THE PRODUCTION OF FIELD CROPS

A TEXTBOOK OF AGRONOMY

BY

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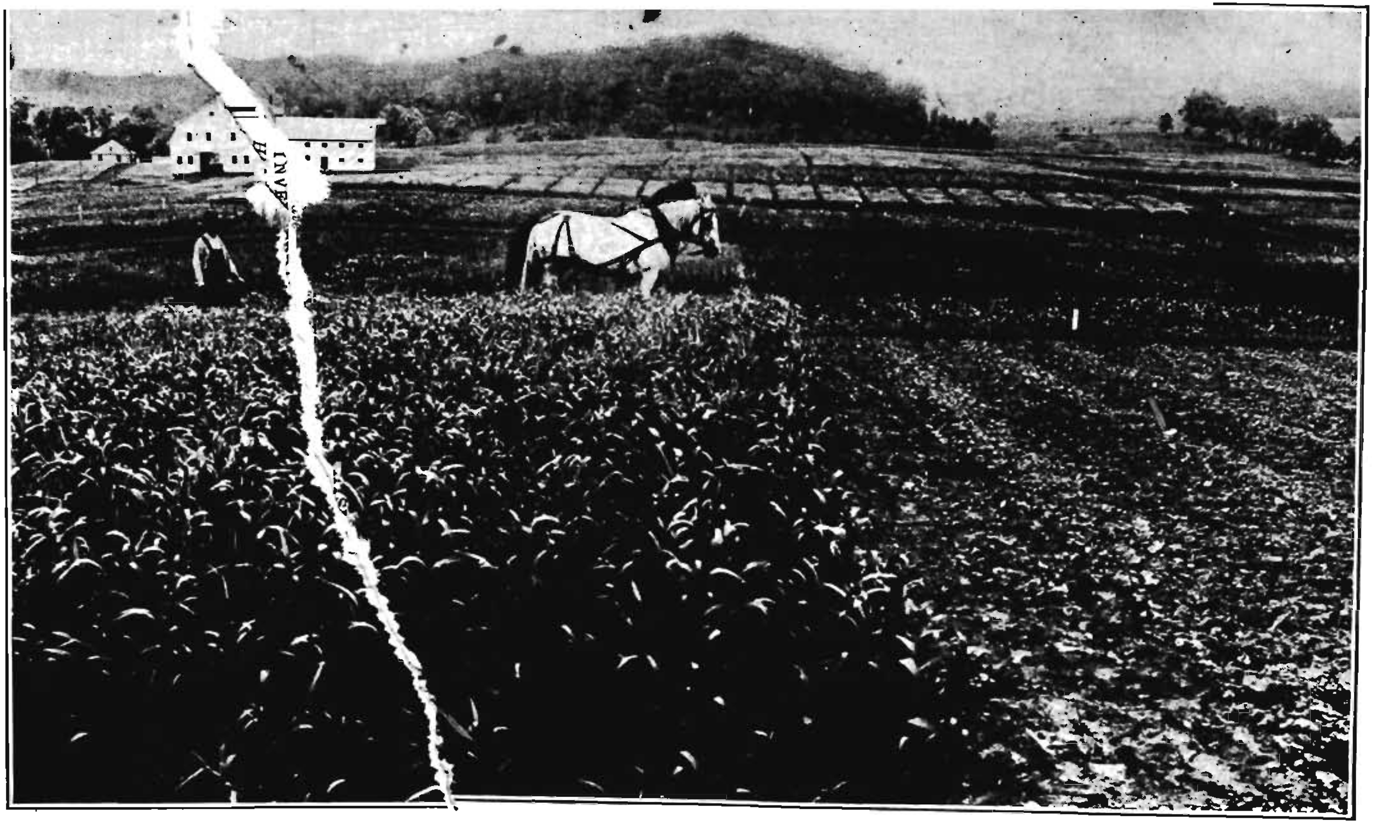

(*Frontispiece*)

A view of a portion of the Agronomy Experimental Plats at the Virginia Experiment Station, Blacksburg, Virginia.

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PREFACE

This book is designed to meet the needs of a standard course in field crops. In its preparation the outline for a standard introductory course in field crops recently adopted by the American Society of Agronomy was followed as closely as practicable. This outline was prepared by a committee of the Society, composed of Dr. W. C. Etheridge of Missouri and Professor M. L. Fisher of Indiana.

It is thought that a knowledge of the fundamentals underlying the production of all crops is desirable before individual crops are treated. For this reason the first part of the book is devoted to a discussion of such fundamentals. In the production of many crops there are also numerous common practices, such as seedbed preparation, seeding methods, the use of fertilizers, and so forth. Such practices are discussed separately with the hope that the student may apply them in their proper place and thus avoid the necessity of repeating a study of these practices under the several crops.

In the discussion of individual crops, no attempt has been made to exhaust each subject nor has the value of any crop been greatly emphasized on account of its relative importance in the country as a whole. It is realized that a crop may be of great local importance and of little national importance.

In short, the aim has been to prepare a text with a wide field of usefulness rather than one with a field limited to certain areas. It is expected that the instructor who may use the text will supplement the information contained therein with data directly applicable to his local conditions.

For valuable assistance given, grateful acknowledgment is made to Dean H. L. Price, who read the chapter on plant improvement; to Dr. F. D. Fromme, who read the subject matter on crop diseases; and to Prof. W. J. Schoene, who read the subject matter on crop insects. The authors also take this opportunity to thank Prof. Lyman Carrier, who revised the chapter on the beginnings of plant culture; Prof. A. B. Massey, who reviewed much of the subject matter pertaining to botany; and Prof. James Duff, who very painstakingly read the entire manuscript.

THE AUTHORS.

BLACKSBURG, VA.,
December, 1923.

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THE PRODUCTION OF FIELD CROPS

CHAPTER I

BEGINNINGS OF PLANT CULTURE

Plant culture began a great many years ago; where and when the beginning took place no one can say. Tribes of primitive peoples in comparatively modern times have cultivated plants and then disappeared without leaving more than a trace of their industry. It is open to conjecture how many such tribes there were prior to the civilizations which have left records of their existence. The earliest peoples of whom we have definite knowledge had made great strides as agriculturists. Perhaps there was a time when the most highly developed races of human beings were no further advanced than are the most primitive savages to be found at the present time. If such was the case, it is easy to imagine the gradual development of agricultural practices over a very, very long period of time. Thousands, probably hundreds of thousands of years, have elapsed since man first appeared on the earth. His greatest material accomplishments during that long period have been the domestication of plants and animals.

Antiquity of American Agriculture.—American agriculture is generally supposed to be not so old as that of Egypt and Asia. The evidence bearing on the subject is negative.

No human remains that bear anything like the antiquity of those discovered in the Old World have been found in America. Modern research is bringing to light, however, evidence to prove that human activity in America is far more ancient than is generally supposed. The finding of a fossil ear of maize by F. H. Knowlton in 1914 indicates the long period of time which has elapsed since that plant was first brought under cultivation. Anthropologists may at any time make discoveries which will change our whole conception of the birthplace of mankind. We have little knowledge of the migrations of the early races but we know that these migrations may have been quite extensive, especially those following the glacial periods. There are evidences that some regions now arid were once productive and were cultivated by man. Consequently in a discussion of the origin of our cultivated crops, all that

can be done now is to show where they were in use and when their earliest evidence appears in history.

Cultivation a Necessity.—At first men lived upon food secured from wild plants and from hunting and fishing. Grim necessity rather than love of plants caused primitive man to domesticate plants. When the supply of food furnished by wild plants and game became insufficient, attention was then turned to agriculture.

Man first cultivated those plants common to his surroundings, as there was but little opportunity for introductions from any considerable distance. The plants chosen were those which were most productive and easiest to grow. Such crops as wheat, maize, sweet potatoes, several millets of the genus *Panicum*, tobacco and other plants, especially the annuals, were early grown. It is found that as time progressed and peoples migrated, plants were introduced from one region into another and that the less desirable plants of one locality were largely replaced by the more valuable ones of other regions.

Antiquity of Cultivation.—The exact time that cultivation started is difficult to state. It must have started at least 10,000 to 12,000 years ago. The people of that period cultivated and ate wheat, barley and millet. Apparently, oats and rye were not known in the Mediterranean region at least. In the pyramid of Gizeh, in Egypt, according to DeCandolle (1886, page 4), was found a drawing representing figs. This pyramid was supposed to have been built 1500 to 4200 B.C. In China, the Emperor in 2700 B.C. began the ceremony of sowing five kinds of useful plants every year. The plants used were rice, yams, wheat and two kinds of millet. It is logical to suppose that these plants were under cultivation before that time. It is probable that agriculture is as old in China as in Egypt and that it started about the same time in the valleys of the Euphrates and the Nile.

The ancient Egyptians and the Phoenicians grew plants along the Mediterranean, and the Aryan nations in their migrations towards Europe about 2500 to 2000 B.C. carried with them plants cultivated in Asia. Plants were, however, probably cultivated in Europe before the Aryan migrations, but the relics of the ancient Danes, 10,000 B.C. or earlier, do not give evidence of cultivated plants. On the other hand, the lake dwellers of Switzerland, 5000 to 4000 B.C., apparently cultivated a few plants. The evidence from the very earliest times shows they had flax, barley, wheat, millet and peas. Oats and a dwarf field bean were added during the Bronze Age.

Regions of Origin.—DeCandolle (1886, page 488) studied the history of 247 species of cultivated plants. Of these he considered 199 originated in the Old World and 45 in America, but as to the origin of the other 3 species he was uncertain. It is probable that the domestication of some plants was carried on independently in different places. Many species

appeared at the same time in the Mediterranean basin and western Asia, in India and the Asiatic Archipelago, in the West Indies, Mexico, and Colombia, and in Peru and Brazil. In some regions there are apparently no native cultivated plants, as in the Arctic and Antarctic regions.

The area covered by the United States has given only a very few nutritious plants worthy of cultivation. Of these may be mentioned the Jerusalem artichoke, the sunflower, the squash and the pumpkin. There were numerous other edible plants which were not cultivated by the Indians. Maize, which was probably introduced from Central or South America, is the most important New World plant.

Patagonia and the Cape have not furnished any of our cultivated plants. Australia and New Zealand have furnished a tree, *Eucalyptus globulus*, and a vegetable, *Tetragonia*, which is not very nutritious. Their floras furnish no grasses corresponding to the cereals, no leguminous plants with edible seeds, and no Cruciferae cultivated for their fleshy roots. The original distribution of cultivated species was apparently very unequal. It had no relation to the needs of man or to the extent of territory.

The advances made by agriculture in ancient times was due to certain more or less well-defined reasons. This statement still holds true in modern times. It was found in the early periods that certain sections were peopled with husbandmen who cultivated plants and had domesticated animals. In other regions agriculture was not so far advanced. It is probable that some peoples appreciated more highly the value of cultivated plants, that the climatic conditions of some regions were more favorable, and again that distance was a handicap to the spread of valuable species.

It was probably due to the favorable climate that rice and several leguminous plants were cultivated at an early period in southern Asia; barley and wheat in Mesopotamia and Egypt; the *Panicums* in Africa; and maize, the potato and the sweet potato in America. Since the climate was unfavorable in the north of Asia, Europe, and America, agriculture probably began in these regions late, but the abundant hunting and fishing obtaining there compensated to a great degree. In Australia, Patagonia and the south of Africa, the native plants were very poorly, and distance prevented the spread of more desirable species from the temperate region, while the insufficiency of moisture and heat probably prohibited the growing of the intertropical species.

It seems that there are three main regions from which agriculture came originally: China, the southeast of Asia with Egypt, and intertropical America.

Existence of Wild Forms.—Of the 247 species studied by DeCandolle (1886, page 457) 193 are said to be known in the wild state; 27 are doubtful, as half wild; and 27 have not been found in the wild form. In order

that a species may exist for a great length of time in the wild state, it must be able to grow and to propagate its kind under adverse conditions.

Some of the species of which the wild form is not known are the chick pea (*Cicer arietinum*), lentil (*Ervum lens*), tobacco (*Nicotiana tabacum*), wheat (*Triticum vulgare*) and maize (*Zea mays*).

These species, with the exception of tobacco, have seeds which are food for animals, birds and insects, and the seeds do not usually pass through the alimentary canal entire. This is probably the main reason for their non-existence in the native form. Also the storage conditions have to be rather favorable, if the power to grow is retained.

It is an interesting fact that all the bread plants of importance and all the economic species of annuals have been domesticated by what we term savage or uncivilized peoples. Since the historical records of civilized man began, there have been a few species of forage crops, mostly grasses, some fruits and ornamentals, which have been brought under cultivation. But during the past 4,000 years there has not been discovered and cultivated a single species of plant which surpasses in value the cereals, sweet potatoes, beans, millets, bananas and sorghums.

The domestication of the American strawberry is one of the most notable instances of modern times where the art of man has improved on the natural wild product.

Spread of Cultivated Forms.—In the early periods there was apparently no wide dissemination of cultivated species. Natural barriers, such as bodies of water, mountains, forests, and deserts, kept the agriculturally inclined races restricted to definite regions, and communication with other races at a distance was unusual. It was only when whole races migrated from one region to another that there was much transporting of cultivated species. The line of demarcation between species of the Old World and the New is much more clearly defined than that between Europe and Asia or Asia and Africa. If the Northmen discovered America in pre-Columbian times, as is quite generally supposed, they apparently did not introduce any cultivated species either from Europe to America or from America to Europe. But after the voyage of Columbus and the circumnavigation of the world, there was a very rapid dispersion of cultivated forms from one hemisphere to the other. Maize, sweet potatoes, cassava and tobacco entered into the agriculture of Africa and Asia at very early dates; and ginger, cinnamon, sugar cane, citrus fruits and other Old World plants were taken to America by the Spaniards soon after the discovery.

In a number of instances species of plants were not cultivated until they had been taken to countries other than their native countries. The Australian eucalyptus was first cultivated in Algeria and the cinchonas of America in the south of Asia. Many of the varieties of the domesticated strawberry trace back to European origin. The evidence indi-

cates that the wild American strawberry was taken to Europe, there grown and improved by crossing and selection. These improved varieties were later brought to America.

The cultivation of new species remained almost stationary during the three centuries preceding and the two or three centuries following the voyages of Vasco da Gama and of Columbus. It was not until the middle of the nineteenth century that new cultivations of much utilitarian value were made. There was, however, during this period a rapid diffusion of cultivated plants already in cultivation.

CHAPTER II

CLASSIFICATION OF FIELD CROPS

The term "field crops," as used in this book, includes all herbaceous plants grown in cultivated fields under a more or less extensive system of culture. In contrast to these kinds of crops, "horticultural crops" may be defined as those crops which are grown under systems of intensive culture in relatively small areas. Under this latter head fall such crops as fruits and vegetables. However, this distinction does not always hold true; fruits may be grown over large areas, and root crops and tobacco require rather intensive cultivation.

Terminology.—It is highly desirable in the discussion of agronomic questions to use a uniform and common terminology. The fact that agronomy is a young science may explain to some extent the differences in existing terminology. As far as practicable the authors will follow the terminology given by Ball and Piper (1916).

Classification.—It is hardly possible to give a classification of field crops which will hold under all conditions. Certain plants are constantly being put to new uses and many crops are used for a number of purposes. The classification will depend largely upon the viewpoint of the reader. Since crops are used for so many different purposes and vary so widely in their botanical relationship, they must be arranged into various groups. Field crops may be grouped from a *botanical* standpoint. In such a grouping the plants are arranged in their evident relationships according to similarity of parts. In order to carry on such a study expeditiously and accurately, a knowledge of the principles of systematic botany is necessary. Again, from an *agronomic* standpoint field crops may be grouped according to their special uses. In such a classification the botanical relationships are not much regarded. Plants that differ widely botanically may be placed in the same group. For example, forage crops include both grasses and legumes. Field crops may be still further classified as *special-purpose* crops. In such a grouping may be included any crop that is used for some special purpose. Rye, for instance, which is generally used for grain purposes, is sometimes used for green manuring. When so used it has a special purpose and should not in this instance be considered under grain crops.

Botanical Classification.—With a few exceptions the important field crops belong to two families, namely, the *Gramineae*, or grass family, and the *Leguminosae*, or legume family. The potato and tobacco

belong to the nightshade family, *Solanaceae;* cotton to the mallow family, *Malvaceae;* flax to the flax family, *Linaceae;* and hemp to the nettle family, *Urticaceoe.*

Grass Family.—The grass family includes practically three-fourths of the cultivated forage crops and all the cereals, except buckwheat. Of the 6,000 known species of grasses, about 1,380 species are grown in the United States.

The grasses are characterized botanically by having alternate leaves with parallel veins and jointed, usually hollow, cylindrical stems, with cross-partitions at the nodes. The basal portion of the leaf, or sheath, encloses the stem, the sheath being open on the side opposite the blade. Where the blade of the leaf joins the sheath is usually found a peculiar appendage known as the ligule. The majority of the grasses are wind pollinated, but there are some exceptions. For example, oats and wheat are normally self-pollinated. The agricultural grasses include *annuals,* persisting for only a single season, and *perennials,* persisting for more than two years. Under the annual grasses may be mentioned the cereals, and under the perennial grasses Kentucky bluegrass, Bermuda grass and Johnson grass. The roots of all grasses are very slender and have few branches, and even in case of perennial forms, new roots are formed each year.

Legume Family.—The legume or pulse family ranks next in importance to the grass family. This group is distinguished botanically by having alternate, compound leaves with stipules. The flowers of field crop legumes are papilionaceous (butterfly-like), as illustrated by the pea flower. The pistil is simple, in fruit becoming a legume, and the embryo usually completely fills the seed. Legumes have been so named from the fact that the seeds are borne in pods each consisting of one compartment containing sometimes one seed, but usually several, as illustrated by the bean. The inflorescence is usually in axillary racemes, as in case of soybeans, vetches and peas, or in heads, as in case of the true clovers. The inflorescence of alfalfa is a spike-like raceme.

Nodules.—The roots of legumes characteristically bear enlargements, called "nodules," which are caused by the activity of the specific bacterium (*Bacterium radicicola*). Each nodule contains a number of bacteria having the power of assimilating atmospheric nitrogen. The activity of these organisms accounts for the great agricultural importance of legumes.

Nightshade Family.—The nightshade family (*Solanaceae*) ranks third in agricultural importance. In it are found the potato, tobacco, tomato and other plants of great economic importance. This family also contains many plants that are deadly poisonous.

Agronomic Classification.—Under this head field crops are classified according to use rather than according to similarity of parts. On this principle, the following classification is often found:

1. *Cereal or Grain Crops.*—A cereal may be defined as any grass grown for its edible grain. The term may refer either to the plant as a whole or to the grain itself. Under such a definition buckwheat is not a cereal, as it does not belong to the grass family. It is, however, usually so classed since the grain is used like the true cereals. "Grain" is a collective term for the fruit of cereals. The six great cereals of the world are wheat, rye, barley, maize, oats and rice. In some countries the millets and non-saccharine sorghums are produced for their seeds. In the United States maize, wheat and oats occupy by far the greatest part of the cultivated area occupied by cereals.

2. *Legumes for Seed.*—The term "legume" may be defined as a plant of the natural family *Leguminosae.* It is also used to refer to the pod of a leguminous plant, consisting of one carpel and usually dehiscent by both sutures. The principal legumes raised for their seeds are field beans, field peas, peanuts, cowpeas and soybeans.

3. *Forage Crops.*—The term "forage" may be defined as vegetable matter, fresh or preserved, utilized as feed for animals. Forage crops include all grasses cut for hay, legumes cut for forage, sorghum and corn fodder.

Among the grasses the chief forage crops are maize, sorghum, millet, oats, barley and certain hay and pasture plants, such as timothy and Kentucky bluegrass. Of the legumes, the clover species, such as common red, mammoth or sapling, and alsike are largely used for hay. Cowpeas and soybeans are important annual hay legumes. The above legumes are often used for pasture purposes, while white or Dutch clover and Japan clover or lespedeza may be classed as distinctively pasture legumes.

4. *Root Crops.*—A root crop is one grown for its enlarged roots. In this group are found such plants as turnips, rutabagas and various forms of the beet. Sweet potatoes are grown to a large extent in the southern part of the United States. The sweet potato is a true root crop, while the potato is not. Many root crops such as turnips, rutabagas, mangels and carrots are far less grown in the United States than in Canada and Europe. In Great Britain, Canada and certain European countries, root crops are much grown.

5. *Fiber Crops.*—Fiber crops are grown for their fiber, which is used in making textiles. ropes, twine, and similar materials. The principal fiber plants of the United States are cotton, flax and hemp. Cotton is by far the most important of the fiber plants and its great acreage and value give to the fiber group the third rank in importance. Ramie, jute and sisal are also sources of fiber.

6. *Tubers.*—The tuber is a much thickened, underground stem, developed on a slender, leafless shoot or stem. The only tuber of importance cultivated in the United States is the potato. It comprises about 25 per cent of the food of the European and English-speaking

peoples. In European countries the potato is grown more extensively, gives larger yields and has a much greater per capita consumption than in the United States. The Jerusalem artichoke and the chufa are also grown for their tubers.

7. *Sugar Plants.*—The principal plants grown for their sugar are sugar cane and sugar beets. The area suitable for the production of sugar cane in the United States is rather limited; the area suitable for the growing of sugar beets is much larger. The bulk of the sugar produced in the United States comes from sugar beets, but most of the sugar consumed in this country is imported because the local supply is insufficient. In addition to this crop, the saccharine sorghums are used for making syrup.

8. *Stimulants.*—Under this head may be included such crops as tobacco, tea and coffee; and of these crops tobacco is by far the most important in the United States.

There are other crops extensively grown in the United States, such as fruits, vegetables and timber crops, which are not commonly classed as field crops.

Special-purpose Classification.—Many of the crops previously mentioned are well suited for more than one purpose. The name of the group is often derived from the purpose for which the crop is used. Some of the special purpose groups are as follows:

1. *Cover crops* are those crops which are seeded so as to make a growth to cover or protect the soil. If a crop serves as a cover crop and is then turned under, it becomes also a green manuring crop. Some of the plants widely used for cover crops are rye, vetch and crimson clover.

2. *Green manure crops* are those crops which are grown to be plowed under or to be disked into the soil to increase its productivity. As a rule legumes are more desirable than non-legumes for this purpose, as they often add nitrogen to the soil. Such crops as soybeans, cowpeas, vetches, clovers, rye and buckwheat are used for this purpose.

3. *Catch crops* are crops used as substitutes for staple crops which, on account of unfavorable conditions, have failed. They are usually quick-growing crops, such as rye, millet and buckwheat. If corn land is seeded to rye in the fall and the rye turned under in the spring and seeded to some other crop, rye could in such an instance be considered a catch crop. It could at the same time serve as a cover, green manure and pasture crop.

4. *Soiling crops* are those crops cut green and fed green directly from the field. Thus, alfalfa, if cut and fed green to animals in the stable or feed lot, becomes a soiling crop. Next to pasturing this is the most primitive way of feeding animals.

5. *Silage crops* are those crops preserved in a succulent condition by partial fermentation in a tight receptacle. The terms "silage" and "ensilage" are synonymous. The chief silage crop of the United States

is corn. However, in those sections where the rainfall is insufficient for growing corn, sorghum is extensively used for silage. Other silage crops are soybeans, cowpeas, millet and sunflowers.

6. *Nurse crops* are those used to protect some other crop sown with them. Grasses and clovers are often sown with grain crops.

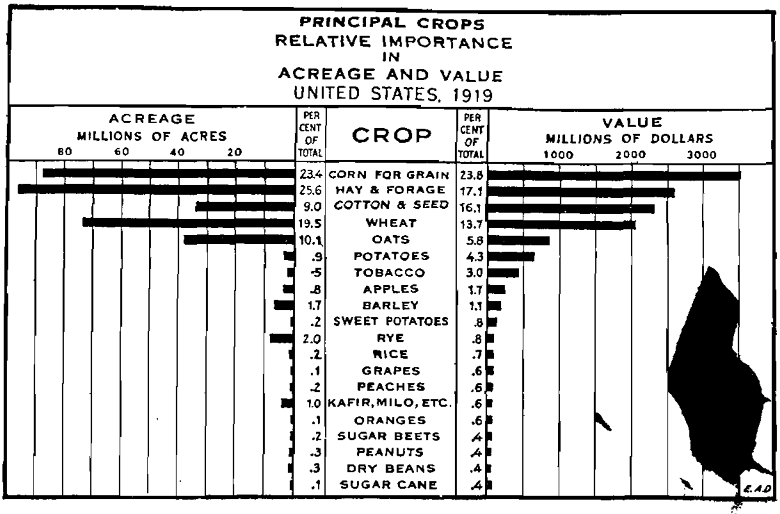

Fig. 1.

Importance of Field Crops.—The relative importance in acreage and value of the principal crops in the United States is shown in Fig. 1, taken from Baker (1922). The five crops, corn, hay and forage, cotton, wheat and oats, constitute about 90 per cent of acreage and over 75 per cent of the value of all crops. Corn is the leading crop in value and if the acreage of corn cut for forage and for silage be added to that of corn for grain, instead of being included with hay and forage, corn would also lead in acreage.

CHAPTER III

ECONOMICS OF CROP PRODUCTION

Profits from farm crops depend upon two factors offering wide fields of enterprise: economic production, and efficient marketing. Since it is not likely that any system of marketing, however effective, will allow a profit to be made from crops which have been produced at a very high cost, the problem of economic production must precede marketing considerations.

Relative Importance of Crops and Other Farm Products.—The relative importance of crops to other products of the farm varies with the region. In the United States as a whole, of every $100 received by the farmers, $36 are derived from live stock, $20 from live stock products, $40 from crops and $4 from miscellaneous commodities. However, the character of the farm sales varies greatly in different sections of the country. In the cotton states it is to be expected that crops will predominate in value. Thus, in Georgia, for every $100 worth of products sold, $75 represent crops, $14 animals, $8 animal products and $3 miscellaneous. On the other hand, in Iowa, for $100 of farm receipts, $63 are derived from live stock, $12 from live stock products, $22 from crops and $3 from miscellaneous sources.

The extremes in variation in receipts per farm vary in the case of live stock from $6 for New Jersey to $63 for Iowa. In the case of live stock products, the range is from $6 for North Dakota to $64 for Vermont. The range for crops extends from $10 for Vermont to $76 for Mississippi.

On January 1, 1920, the value of crops exceeded that of live stock and live stock products by $4,074,967,813. If the income from forests, nursery and greenhouse products is combined with that from live stock and live stock products, the value of crops exceeds their combined values by $3,582,831,366.

Briefly, it may be said that crops are significant in that they have a high value *per se*, are important in domestic and foreign trade and are essential to the existence of the animal industry.

Factors of Crop Production.—The amount of the different crops produced depends upon many factors. Some of these factors are under control of the farmer, while others are not. Some of the factors which are more or less under the control of the grower are choice of good seed of the best varieties, selection of suitable land, judicious fertilizing, proper systems of cropping and wise cultivation. The factors often not con-

trollable are weather, pests, diseases and so forth. It may be readily seen that the amount of crops produced may be determined by factors beyond the control of the farmer. Likewise, the grower may exercise considerable influence on the yields of crops.

Influence of Crop Yields on Community Prosperity.—The general prosperity and progress of a community are affected by the success or failure of its crops. It is desirable for the production of crops to be such that the producer will receive a reasonable profit and that the price to the consumer will be fair. Either over-production or under-production may prove disastrous first to the farmer and later to the nation. The amount of crops produced or the relative price received for them, or both, may affect the general business of the country in several ways: (1) Crops influence to a large extent the buying power of a community; (2) the solvency of farmers and those associated with them in business ways depends upon the profitableness of crop production; (3) the export trade depends to a great extent on the amount of crops produced; (4) transportation interests are influenced by the size and distribution of crops; and (5) industries using crops as raw materials are affected by the amount of crops.

Crops the Most Important and Cheapest Source of Food.—With the increase in population the tendency has been to decrease the number of animals used for food and to increase the acreage planted to crops. It requires more land to produce live stock than to grow grain. In other words, more food can usually be secured in the form of crops, from a given acreage, than in the form of animals.

Why Food Has Been Cheap in the Past.—In former years food was comparatively cheap. This condition was due to several factors, chief among which were free or cheap land, cheap labor and the invention of labor-saving machinery.

Free or Cheap Land.—Soon after the Civil War the then unsettled West offered great areas of highly productive virgin soil. Much of the land could be homesteaded without cost and all agricultural lands were cheap. Since lands were so cheap, it was not considered economical to make expenditures for maintaining the productivity of the soil, and for a time food was produced at a very low cost. At present much of the best land of the country has been reduced in yielding power by failure to follow practices which will maintain productivity. Then too, since the rapidly increasing population has brought about an increase in land values, a considerable portion of the cost of producing crops is now for maintaining the productivity of the soil and paying interest on money invested in land.

Cheap Labor.—Labor is a considerable item of expense in the production of crops. Moorehouse and Juve (1921) report that one-fifth of the cost of production of corn in the corn belt may be charged against

man labor, and in the eastern areas one-third. This cost for cotton in South Carolina amounted to 54.3 per cent, and in Texas to 38.1 per cent. In the case of tobacco in Kentucky, the man-labor cost constituted 42 per cent. The increased cost of labor in recent years means that the production of crops is more expensive now than formerly.

Invention of Labor-saving Machinery.—During the past fifty years rapid strides have been made in the invention of better and more improved machinery. The large amount of crops produced per individual worker in the United States is due, in a large measure, to the improved types of machines in use. Each improvement had in view more efficient and profitable production per unit of man labor. In short, the improved farm implements are labor-saving devices. This condition, together with abundance of productive land and a plentiful supply of labor, tends toward an over-production of crops. However, with the increase in population, especially in cities as compared with the rural districts, food prices are higher now on the average than in the past.

Future Production of Cheap Food.—With increasing population the question of cheap food for the future is an important consideration. In order to produce crops profitably and at the same time furnish them to the consumer at a reasonable price, there are several things worthy of consideration. Among these factors may be mentioned: (1) Maintenance of the productivity of the soil; (2) the use of improved cultural methods, (3) the use of good seeds of improved varieties; (4) the control of insect pests and diseases; and (5) the economic use of labor.

Maintenance of the Productivity of the Soil.—A productive soil is of first importance in the economic production of crops. It is obviously necessary that land produce well before the largest profits can be secured. The farmer who farms highly productive land is less affected by extreme fluctuations in crop values and variations of seasons than one who farms less productive land. Within certain limits the unit cost of production decreases as the acre-yield increases. Even under very adverse climatic conditions, a fair crop may be secured from very productive soil.

Improved Cultural Methods.—Good cultural methods are necessary for high production. Proper culture aids in the liberation of plant nutrients, the aëration of the soil, the conservation of soil moisture, the destruction of weeds and the prevention of erosion. Good methods should be used from the time the preparation of the land is begun until the crop no longer needs cultivation.

Improved Varieties.—The use of good seeds of high-yielding, adapted varieties is one of the best means of producing large crops. It is evident that the quality and preparation of the soil cannot overcome the serious consequences arising from the use of poor seeds. The differences in yield between varieties is often sufficiently great to determine whether the crop will be produced at a profit or at a loss.

Control of Crop Enemies.—The damage done to crops by certain enemies is enormous. The Hessian fly probably reduces the yield of wheat one-tenth on the average and often the percentage of loss is higher. Corn is frequently badly affected by the chinch bug and the corn ear worm. The grasses and forage crops are reduced in yield by such insects as cutworms, wireworms, white grubs, grasshoppers and other insect enemies. Cotton yields are greatly reduced by the boll weevil, bollworm, and leafworm. The flea beetle, budworm and hornworm often greatly reduce the yields of tobacco. Stored products are subject to damage by insects. The losses are difficult to estimate, but they will reach high percentages. It is estimated that 10 per cent of each of the following crops are lost annually on account of insect pests: cereals, hay and forage, cotton and tobacco. These losses can be very materially reduced by the wiser use of control methods.

Economy of Labor.—Man labor and horse labor are usually the principal items of cost in producing crops. According to Peck (1920), in the production of wheat in the winter and spring wheat areas, these items make up one-third of the total cost. Moorehouse and Juve (1921) found that in New York 27.3 per cent of the cost of production of potatoes was spent for man labor and 24.7 per cent for horse labor. It is evident that any system that will maintain crop yields and economize in labor will reduce materially the cost of production. Economy in the use of labor will depend largely upon the managerial ability of the owner, the use of labor-saving machinery and other factors.

Relation of General High Production to Profit.—The invariable slump that comes in the prices of crops whenever even a slightly larger production than the normal for the United States is obtained, would seem to indicate that the methods now used are good enough and that improved methods are not necessary. A glance at the figures given in the United States Department of Agriculture yearbooks will show that a large production of any of the staple crops for the United States is usually accompanied by a lower price per unit of measure and a lower acre value. With intensively cultivated crops, such as tobacco and potatoes, this is particularly striking. It is so much so that every tobacco and potato farmer realizes that there is nothing more diastrous to profits than for the country as a whole to produce a very large crop. This would indicate that the crops produced in a normal year in the United States are sufficient to meet the market demands and that an abnormally large crop gives a supply in excess of the demands, which results in a lack of competition for products in the markets and a corresponding decline in prices.

This condition can be remedied to a certain extent by better systems of marketing. At the present time most of our crops are placed on the market as soon as they are harvested. In cases of very large crops this

brings about gluts, due to inability of the small markets to handle and store such unusual amounts. These gluts always result in a decided break in the price. Better systems of marketing will avoid these gluts and their disastrous results by storing products and placing them on the markets more opportunely. However, there is no system of marketing that will sell at a high price all of a crop that exceeds the demand.

Relation of Individual High Production to Profit.—While the preceding paragraph shows that an exceptionally large production of any crop for the country as a whole will create a supply greater than the demand and will usually result in lower returns per acre, profits for the individual are absolutely dependent upon yields which are higher than the average. No system of marketing under present conditions can make a 14-bushel crop of wheat or a 20-bushel crop of corn very profitable. With present prices of labor, seed, fertilizer, land and farm products, it takes 10 to 15 bushels of wheat and 20 to 30 bushels of corn to pay the cost of production. Manifestly, the individual farmer who does not produce yields higher than these cannot expect to make a comfortable living.

Warren and Livermore (1911) show that of 1,317 farms in one county in New York, 13 made labor incomes of over $2,000. The crop yields on these farms averaged 27 per cent higher than the average for the region. The average yields of crops for the region were hay 1.3 tons, oats 33 bushels and potatoes 120 bushels. The average yields on the most profitable farms were hay 1.6 tons, oats 43 bushels, and potatoes 219 bushels. In another New York county, out of 671 farms, 19 made labor incomes of over $2,500. The crop yields on these 19 best farms were 18 per cent higher than the average, even though the yields in this county were exceptionally good and far above the average for the state. While other factors doubtless help to make these farms successful, these figures indicate a strong relation between high production and high profits.

While it takes many things other than high production to insure profits from farming, it is hardly possible to make large labor incomes on farms where the average crop yields are not well above the average for the region.

Most Productive Methods Not Necessarily the Most Profitable.—At a given price per unit measure of product, after a certain yield is reached with any crop, the profits from further intensive methods of culture begin to diminish; and if too great a degree of intensity is practiced, the increased cost of production may become greater than the value of the increased crop produced thereby. Just how far it is advisable to increase yields by better methods is a practical problem. It is said that one of the largest yields of corn ever made in the United States was produced at a loss, if the crop alone had been the only source of income. This corn crop produced more than 200 bushels to the acre, but the producer used the most intensive systems of fertilizing and

cultivating. A system of irrigation was installed to insure an optimum amount of water for the crop at all times. The total cost per acre for producing this crop is said to have been something over $500. The corn from this acre would have had to sell for a very high price to pay the cost of production, but the farmer who grew it won $1,000 in prizes. So the end justified the means. However, no farmer who has to sell his crop for the usual market price would be justified in using the methods followed by this individual. The proper degeee of intensity to be used in crop production can only be found by an accurate determination of the point where increased intensity fails to pay. A given number of cultivations may pay well on a crop and additional cultivations may further increase yields, yet the increased yield due to the additional cultivations may not be sufficient to pay for their cost. In like manner, the application of a certain amount of a certain kind of fertilizer may be necessary to insure profits from a crop, and larger amounts or better grades of fertilizers may materially increase yields, yet their use is not justified unless they more than pay the extra expenses incurred. It should be remembered that not only do the expenses involved in using a fertilizer include the cost of the fertilizer, but they also include the cost of hauling and distributing the fertilizer, and of harvesting, storing and marketing the extra crop produced.

The degree of intensity to be practiced in producing crops is governed largely by the selling price of the products. When the prices of crops are high, a considerable expense is justified in their production; but when prices are very low, the point of diminishing returns from intensified methods is reached very quickly.

The object of the farmer should not be to produce the largest yield possible to the acre, but to obtain the largest *economic* yield.

CHAPTER IV

GERMINATION AND GROWTH

Means of reproduction are necessary for the perpetuation of all living organisms. In case of the ordinary cultivated field crops new generations are usually reproduced by means of seeds. In the production of crops it is necessary first to study the factors essential to the germination of seeds, as this process is one of the first steps concerned in plant growth. The seeds are used not only to reproduce the new generation of plants but frequently to furnish food for man and animals. In the seed the plant stores up food to be used at some future time. The corn plant stores up food in the kernels for the young plant to use, the potato in the tuber, and the sweet potato and beet in the roots. It is this stored food, whether it be in the seed, tuber, or root, that serves as food for the young plant until it is sufficiently developed to utilize the plant nutrients in the soil.

Seed Structure and Composition.—The essential parts of seeds are as follows: (1) the young dormant plantlet or embryo or germ; (2) the stored food, which in the cereals is outside the embryo and known as the "endosperm," and in the legumes is in the cotyledons, a part of the embryo; and (3) the seed coat, a protective covering, which may consist of one or more layers.

In the cereals the endosperm is mostly starch, while the germ is high in protein, oil and minerals. In the case of legumes the entire seed, which consists of the embryo and seed coat, is relatively high in protein. The mineral constituents of various seeds are given by McCarthy (1894). The amount of ash in red clover seed is given as 4.5 per cent; in rape seed, 4.44 per cent; in buckwheat seed, 1.37 per cent; in winter wheat, 1.97 per cent; in spring wheat, 2.14 per cent; and in corn, 1.51 per cent.

Qualities for Germination.—In order that seeds may germinate perfectly, it is usually necessary that they be well developed and have vigorous germs and an abundant supply of stored food. In addition they should have been stored in such a way as to retain high viability and vitality. The superiority of well-developed seed of high quality over inferior seed is discussed in Chapter VIII.

Duvel (1904) found that the main factor affecting the vitality of seeds is their moisture content. *He found that seeds retain their vitality well* if thoroughly air-dried as soon as mature and kept in a dry place. It was found that seeds with a high percentage of moisture deteriorate very

quickly even when stored under dry conditions. Duvel stored several different kinds of seeds, mostly vegetable, in paper envelopes and in corked bottles under different conditions at various places. The seeds were stored at San Juan, Porto Rico; Lake City, Florida; Mobile, Alabama; Auburn, Alabama; Baton Rouge, Louisiana; Wagoner, Oklahoma; Durham, New Hampshire; and Ann Arbor, Michigan. The seeds were stored under the following conditions: (1) under trade conditions or in ordinary unheated rooms; (2) in dry rooms, that is, rooms in buildings which were heated during cold weather; and (3) in basements of comparatively low and uniform temperature and high relative humidity. When envelopes were used as seed containers, the average loss in germination after storage for 251 days was: under trade conditions, 36.63 per cent; in dry rooms, 21.19 per cent; and in basements, 42.28 per cent. When corked bottles were used, the average loss in germination was, under trade conditions, 3.92 per cent: in dry rooms, 8.08 per cent; and in basements, 4.51 per cent.

The results reported by Duvel also show that seeds of high viability deteriorate less in storage than seeds of comparatively low viability.

Conditions Necessary for Germination.—The three conditions necessary for germination are: (1) sufficient moisture, (2) sufficient aëration and (3) sufficient heat. A certain inter-relationship exists between these factors. The optimum amount or degree of any one of these factors will depend on the degree of existence of the other two. It has been found that high temperature favors the germination of cockle bur seeds because of greater diffusion of oxygen under such conditions. A direct relationship between several factors, such as temperature, oxygen and carbon dioxide, control germination. Thus, in considering the optimum conditions for any one of the three factors, one must take into account the relations existing among them. It is, therefore, difficult to state the optimum condition for any one factor.

Moisture.—At the North Carolina Experiment Station, McCarthy (1894) found that the presence of a quantity of water sufficient to cause the seeds to swell is the first and most important requirement. Quoting from Nobbe he states that the water absorbed by wheat in swelling amounted to 60 per cent of the dry weight; by corn, 39.8 per cent; by white clover, 89 per cent; by alfalfa, 87.8 per cent; and by rape, 48.3 per cent.

Aëration.—The necessity of oxygen for germination may be easily shown by experiment. If the soil is compact and water-logged so that no air can reach the seeds, they will usually decay. This is one of the reasons for keeping soils well drained and aërated. However, rice and some other seeds will sprout in mud or water.

Temperature.—The amount of heat required will vary with the kinds of seeds. Some seeds, such as those of clover and oats, will grow at a rather low temperature, while the temperature requirement for best growth is higher for the seeds of corn and beans.

McCarthy (1894), quoting from Sachs, states that the optimum temperature for germination of corn, beans and pumpkins is 91° F., and for barley and wheat 84° F. The results also show that corn, German millet and timothy seeds will not germinate at a temperature of 40° F., but that such seeds as winter wheat, alfalfa, red clover and buckwheat show some germination at this temperature.

Process of Germination.—The dry seed is in a dormant state, but when it is placed in the proper environment germination and growth begin. These processes start in most seeds in a few days after they are placed under favorable conditions. The radicle first emerges from the seed coat and grows downward and soon the shoot axis, or plumule, breaks through and grows upward. In the process of growth the moisture taken up by the seeds carries in solution part of the stored food which, if starch, is changed by enzymatic action into sugar. For a few days the young plant feeds upon the food furnished by the seed. When the plant reaches sunlight and new leaves begin to form, a new set of true or permanent roots forms just below the surface of the ground, and the temporary roots die. The plant now begins to feed upon the nutrients secured from the soil and from the food manufactured in the leaves and is no longer dependent upon the seed for sustenance.

Sources of the Elements Required for Growth.—There are ten elements necessary for plant growth as discussed in Chapter XI. Of these ten elements, four are secured from the air and water, namely, carbon, hydrogen, oxygen and nitrogen. Nitrogen is taken from the air by certain groups of bacteria. The nitrogen thus assimilated by these organisms undergoes a change before it is used by higher plants. The nitrogen used by all plants comes directly or indirectly from the air. The bacteria taking nitrogen from the air may be associated with most, if not all, leguminous plants. Bacteria of this nature are also associated with non-leguminous plants.

There are six elements which come from the soil, namely, sulphur, phosphorus, potassium, calcium, magnesium and iron. The nitrogen, which is taken from the air by bacteria, is first combined in the soil to make soluble compounds before it can ordinarily be used by higher plants. Therefore, it is usually stated that seven elements come from the soil and three from the air and water.

Throughout the inert mass of soil is to be found varying quantities of the essential elements in the form of chemical compounds. Through certain agencies the compounds gradually become soluble in water and the plant nutrients are removed from the solution by the plants.

Parts of a Plant.—The plant is ordinarily divided as follows: (1) the root system; (2) the vegetative part, made up of stem, branches and leaves; and (3) the reproduction part, made up of flowers, fruits and seeds.

A function of the roots is to absorb water and plant nutrients from the soil. The water and nutrients are conducted through the stem and branches of the plant, while the leaves give off or transpire the excess water, assimilate carbon dioxide from the air and manufacture food for growth of the plant from the materials taken from the soil and the air.

How Water and Nutrients Are Taken from the Soil.—The roots of plants ramify through the soil in all directions. Some plants, such as alfalfa and most of the clovers, are classed as deep-rooted plants. Other plants, such as the pasture and hay grasses and corn, although comparatively shallow-rooted, produce a rather extensive lateral growth. As long as the plant is growing new branches, roots are being formed; and on the new roots are produced the root-hairs. The root-hairs are minute, single-celled organs produced near the tips of the new roots. These root-hairs live and function for only a short time; and as the roots extend, new root-hairs are produced. With few exceptions the root-hairs and not the roots absorb the water and nutrients from the soil.

Absorption of Water.—The cell wall of the root-hair acts as a semi-permeable membrane and the water is absorbed by osmosis. The root-hairs contain sap which is ordinarily more concentrated than the soil solution. As a result the water from the soil passes through the cell wall into the root-hairs and continues its course as long as the difference in concentration is maintained. As long as the soil solution is less concentrated than the cell sap, the movement of water will be inward. If the soil solution becomes the more concentrated, as sometimes happens in alkali soils, the movement of the water is from the root-hairs into the soil solution and plasmolysis results. This may be the cause of wilting in plants.

Absorption of Nutrients.—The nutrients are absorbed by the root-hairs independently of absorption of water. It is necessary, however, that the nutrients be in solution and that sufficient water be present to allow the dissolved nutrients to diffuse. The nutrients are absorbed by the process of diffusion. Before being absorbed the nutrient compounds are usually ionized into their component ions and there is usually an absorption of ions. The dissolved substance is ordinarily called the "solute" and the water in which the solutes are dissolved is called the "solvent." A solution may contain several kinds of solutes in a common solvent. The solutes tend to become equally diffused in the solvent or solution. If two solutions which have a common solvent and which contain different solutes or the same solutes in unequal proportions are brought together, being separated only by a semi-permeable membrane, the solutes tend to pass through the membrane and reach an equilibrium. In the case of absorption of the nutrients from the soil, after the compounds have been ionized, there is a passage of ions from the soil solution through the cell walls of the root-hairs into the cell sap solution until an equilibrium has

been obtained. For example, in case potassium nitrate (KNO_3) is added to the soil, the compound dissolves and usually becomes ionized into K^+ and NO_3^- ions. The former are positive and known as "cations" and the latter are negative and called "anions." If the cell sap contains as many NO_3 ions as the soil solution, there is no transfer of these ions through the cell wall. On the other hand, if there are fewer K ions in the cell sap than in the soil solution, the K ions tend to pass through the cell wall until an equilibrium is reached.

Thus, the passage of water through the cell wall of the root-hairs is independent of the passage of nutrients. In other words, the passage of water is from the solution of lower total concentration to the solution of higher total concentration. In the case of nutrients there is a tendency for the ions of the particular nutrient compounds to reach an equilibrium regardless of the total concentration of the two solutions.

Transpiration.—Plants need a certain amount of water in carrying on their physiological processes. However, much more water is absorbed from the soil than is retained by the plants. The excess water passes from the plant through the stomata of the leaves, and this process is called "transpiration." The amount and rate of transpiration depends upon several factors, the chief one being light. Other things being equal, transpiration is greater in bright sunlight. Montgomery and Kiesselbach (1912) in Nebraska have shown that more water is transpired in a dry climate than in a humid one. Briggs and Shantz (1913) report results which show that when grown in rich soils, plants transpire less water per unit of dry matter produced than when grown in poor soils. Montgomery (1911) states that the amount of water lost by transpiration from the plant and by evaporation from the soil for each pound of dry matter produced by various plants is as follows: wheat, 225 to 650 pounds; barley, 262 to 774 pounds; oats, 402 to 665 pounds; corn, 233 to 400 pounds; and red clover, 249 to 453 pounds.

Photosynthesis.—The food used in growth by green plants is manufactured in the leaves. The process is known as photosynthesis. In the process the carbon dioxide assimilated by the leaves through their stomata is combined with water to form carbohydrates. From simple carbohydrates proteins are produced by the addition of certain mineral nutrients. Sunlight and cholorophyll seem to be necessary for photosynthesis to proceed efficiently. The process is probably very complex and it has not been definitely determined how all the reactions take place.

Among the factors concerned in photosynthesis may be mentioned light, carbon dioxide content of the air, temperature, cholorophyll content of the leaf, stomata, oxygen, nutrients, removal of products, and water supply.

The importance of photosynthesis to the life of plants should be appreciated since from 85 to 90 per cent of dry matter is made up of

organic materials manufactured in the leaves. The materials made by this process are used by the plant primarily as a source of energy and also as a means of building up other materials.

Food Storage.—As the organic compounds are formed in the leaves, they continually move to other parts of the plant. However, before the compounds, which are comparatively insoluble, are translocated, they must be changed to a more soluble form, a change which is brought about largely by enzyme action. The portions of the compounds not used by the plant as food are stored by it for future use, most commonly for use in reproduction.

After being translocated the soluble compounds are changed again to relatively insoluble forms. The most common types of stored foods are: (1) Carbohydrates: poly-, di- and mono-saccharides; cellulose, gums and starches; (2) fats; and (3) proteins.

In the ordinary field crops the food is stored largely in the reproductive parts.

Reproduction.—Most of the field crops are reproduced from seeds. The new individual begins, not when germination of the seed takes place, but when the generative nucleus of the pollen tube unites with the egg-cell nucleus of the ovule. After the fusion of the pollen and egg nuclei, a portion develops into the embryo or miniature plant, and, in case of cereals, a part into reserve food or the endosperm. The whole is known as the "seed." The covering of the seed in grains is a remnant of the old ovary enclosing the stored food and embryo.

The organs concerned in reproduction are the pistil and stamens. The pistil is the female organ and is composed typically of (1) the ovary, which forms the base of the pistil and contains the ovules; (2) the style, a more or less elongated portion of the pistil bearing the stigma; and (3) the stigma, or the portion of the pistil which receives the pollen grains. The stamens are the male organs of the plant. Each stamen is made up of (1) a thread-like filament or stalk, and (2) the anther, which is borne on or near the apex of the filament and bears the pollen grains.

When the time arrives for reproduction, the anthers open and release the pollen grains and these find lodgment in many instances on receptive stigmas. Soon pollination is accomplished, the pollen grain germinates and the pollen tube penetrates into the stigma and down the style into the ovary. Here fertilization takes place and as a result the seed is produced.

Pollination.—If the pollen from a plant fertilizes the ovules of the same plant, the plant is said to be self-fertilized. This is the case in wheat, oats and barley. If the pollen from one plant fertilizes the ovules of another plant, the plants are said to be cross-fertilized. Rye and corn are plants commonly cross-fertilized.

CHAPTER V

ADAPTATION OF CROPS

As a general rule crops are not profitable unless they are well adapted to the region in which they are produced. In other words, if the average farmer is to raise crops successfully, the crops must be productive and easy to grow under the existing conditions.

There are three groups of factors which determine whether certain crops can be economically produced in given regions, namely, climate, soil and economic conditions.

Examples of Crop Adaptation.—Waller (1918) has given three centers of crop production in the United States, namely, the Atlantic Coast to the Great Plains, the Plains, and the Pacific Coast. In each of these regions certain crops predominate.

The mention of a few examples will suffice to show the distribution of crops. Cotton is grown in the southern states. About three-fourths of the tobacco is raised in the states of Kentucky, North Carolina, Virginia and Ohio. Peanut production is limited largely to the southern states bordering on the Atlantic and Gulf coasts. Corn is primarily the crop of the corn belt, about two-fifths of the acreage being in the four states of Illinois, Iowa, Kansas and Nebraska. In the case of wheat the four states of North Dakota, Kansas, Minnesota and South Dakota have two-fifths of the total acreage of the country. The three states of North Dakota, South Dakota and Minnesota produce practically all the spring wheat grown in the United States. Oats yield much better in the North than in the South. Cowpeas and soybeans, on the other hand, thrive more luxuriantly in the South than in the North. The hay and pasture grasses grow better in the cooler sections, other things being equal, than in the warmer sections. However, certain grasses, such as Johnson grass and Bermuda grass, are peculiarly adapted to the South, while timothy and the bent grasses are adapted to the North. Kentucky bluegrass thrives best in the rich limestone regions of the country. The sorghums are produced to the greatest extent in the regions where the rainfall is light and the summers are hot. Buckwheat is produced almost entirely east of the Mississippi River, and then practically always on the hilly and mountainous lands. Thus, certain crops are more or less sharply confined to certain regions of the United States.

Factors Determining the Adaptation of Crops.—The distribution of crops is determined largely by their adaptations. If the climate and soil

conditions are favorable for the requirements of the crops, then, other things being equal, they can be successfully and profitably grown. However, an important factor to be considered is the economic conditions prevailing in particular sections. The mere fact that a particular crop is suited to the soil and climate does not prove that it should be grown. It is necessary to consider such items as transportation facilities, distance to market, market demand and supply, capital required, labor supply and so on.

The adaptation of crops to climate is shown by the fact that certain plants are indigenous to the tropical region, others to the frigid and still others to the temperate, although the soil conditions may be practically the same.

In case of adaptation of crops to soils, the importance of this relation is second only to the climatic factor.

Thus, the four factors determining the desirability of growing any crop in a particular region are: (1) the adaptation of the crop, (2) the climatic condition of the region, (3) the soil condition of the region and (4) the economic situation.

Crop Adaptation.—In regions to which certain crops are especially adapted, the first evidence of special adaptability is usually shown by the number of farmers growing those particular crops, and also by the fairly good yields produced on even the rough, hilly and comparatively poor lands. Of these crops, of which there are usually a number of varieties, the plants are above the ordinary in size and luxuriance of growth. On the other hand, as these crops are removed from their favorable environment, the converse is found.

As crops are farther removed from the regions of especially favorable climate, more attention on the part of the farmer is necessary. They must be grown on the richest land, given good cultivation and treated indulgently in many ways. The struggle for existence in competition with the better adapted plants becomes severe; and frequently, unless aided by man, the introduced crops fail to survive for any great length of time.

The Climatic Requirements for Certain Crops.—The climatic requirements for crops are even more exacting than the soil requirements. Nature has equipped certain crops for resisting droughts; others thrive under excessively moist conditions. Some luxuriate under the burning sun of the tropics, while others give optimum returns only in temperate climates.

Corn.—The corn crop does best in sections where rainfall is abundant, nights warm, days mostly warm and bright, and the frost-free period 125 to 150 days. Varieties and strains of corn have been developed for every section of the United States where there is sufficient rainfall, but the bulk of the corn crop is produced in the upper Mississippi Valley where the climatic conditions are those enumerated above.

Wheat.—Wheat is grown mostly in regions where the winters are cold, although there are some notable exceptions, such as California, Egypt and India. Practically three-fourths of the wheat crop of the United States is grown where the average January temperature is below freezing and where the mean annual temperature is between 45 and 60° F. However, taking the world as a whole, we find that wheat has a very wide climatic range and that this range is being extended by climatic adaptations. Weather affects both growth and quality in wheat, a high moisture content in the soil during the early stages of growth is conducive to tillering and a cool spring is most favorable to largest yields of best quality grain. Those localities which have extremes of temperature and rainfall generally produce the hardest and reddest grains; but sunny climates, with moderately dry weather during the ripening period, make brighter grains, which in turn produce a higher quality of flour.

Oats.—Oats do best in cool, moist climates. If ample water is provided, the crop may be successfully grown in rather warm climates, but the oat crop requires more water per pound of dry matter produced than any of the other important cereals. The greater part of the oat crop of the United States is produced in those states bordering on the Great Lakes. Winter oats are grown chiefly in the South. The crop is sown in the early fall and ripens in the early summer, thus having for a growing season that part of the year when the season is cool and moisture abundant.

Potatoes.—The climatic requirements for the potato crop are very similar to those for oats. Potatoes require cool, moist weather for best development. The enormous potato yields of certain European countries is due more to a favorable climate than to soil conditions and cultural methods. The chief potato growing sections of the United States are north of the best corn lands. The potato crop of the South is made possible by very early spring planting. In this way the crop matures before hot weather comes, or the crop is planted in late summer to mature during the cool weather of autumn.

Cotton.—This crop requires a long growing season with hot days and nights. It is a common saying in the South that cotton never grows well until the nights get too hot for sleeping under cover. Protracted rainy spells are unfavorable to the growth of cotton. Occasional showers followed by bright, hot weather afford ideal weather conditions for the crop. The southern part of the United States has almost ideal weather conditions for cotton, producing approximately three-fourths of the cotton crop of the world.

Grasses and Clovers.—There are good grasses and clovers for all climates. In the United States timothy, red clover and Kentucky bluegrass thrive luxuriantly in the cool, moist climate of the northeastern section. Farther south these plants become less important, except in

the higher altitudes, and they are supplemented by Bermuda grass, Johnson grass, lespedeza and carpet grass, which will withstand the hot, dry periods common to the southern region. Brome grass is also adapted to the cold, dry conditions of the northwestern section of the country.

Practically all crops are rather limited in their adaptation to climatic conditions but the illustrations will suffice to show the importance of this relation.

Choice of Soil to Suit Crop Needs.—The external factors of plant growth are: (1) mechanical support, (2) air, (3) heat, (4) light, (5) water and (6) nutrients. With the exception of light, the soil supplies all of these, either wholly or partly. Not all soils are alike in their ability to supply these factors, and different kinds of plants vary in the degree of their requirements. For this reason one of the duties of the farmer is to find the crop particularly adapted to his soil.

Kind of Soil Required.—From observations and experiments it has been found that certain crops are adapted to certain kinds of soil. As a rule, the small grain and grass crops flourish most luxuriantly on the heavier classes of soil, such as clays and clay loams. Corn, however, does best on loams and slit loams, while potatoes and truck crops give best results when planted on loams or sandy loams. Of course we do not mean that these crops cannot be grown profitably on other soils, but that, other things being equal, they will give best results on the soils mentioned. Crops requiring a large amount of cultivation usually give best results on the soils of coarser texture, as these soils are more easily worked and are less affected by rains and dry weather. Such soils are usually called "light" soils on account of the fact that they are more easily worked, though their volume weight may be heavier than that of the finer textured soils. The potato crop may be cited as a crop which is usually grown on the lighter soils, even though it often gives splendid yields on heavier soils. In the case of this crop, farmers prefer light soils, since the soil must be worked a number of times in planting, cultivating and digging, and since this work is more easily and cheaply accomplished on light than on heavy soils. This is one reason why truck crops, which require a large amount of cultivation, are usually grown on light soils. On the other hand, grasses and small grains require no cultivation after seeding and can, therefore, be profitably grown on heavy soils. Generally speaking, heavy soils contain more plant nutrients than light soils, and give more profitable returns from those crops which do not require much cultivation of the soil.

Soil Water.—The water-holding capacity of soils has a great influence upon the profitableness of crops that may be grown upon them. For example, grains and grasses do best on soils of high water-holding capacity, while cotton, peanuts and tobacco do best on easily drained soils.

Soil Heat.—The warmth of soils is largely dependent upon their water-holding capacity. This is another reason why truck crops, which must mature early to be most profitable, are usually grown on soils which dry out quickly. The drier, coarser-textured soils become warm early in the spring; thus the crops get a quicker start and therefore mature earlier.

Soil Nutrients and Organic Matter.—The supply of soil nutrients and organic matter is important. Tobacco must be well supplied with the plant nutrients but the highest quality of bright or flue-cured tobacco is produced on soils low in organic matter. With sun-cured, dark or shipping, and Burley tobacco an abundant supply of both nutrients and organic matter is desirable. The best corn lands are well supplied with plant nutrients and organic matter, and the same is true of wheat. Waller (1918) states that the spring wheat center has its present location because of the great level expanse of rich soil left after lowering of Lake Agassiz.

Modification of Soil and Climate for Crop Needs.—It is often advisable to modify conditions to meet the special adaptions of plants. Corn, which is especially adapted to the corn belt, is grown in all parts of the country, but in such sections as New York, eastern Pennsylvania, and the New England States, the crop should be planted only on the best lands and should be especially well cultivated.

In case of cold frames, greenhouses and small vegetable gardens, where the products grown have a high value, both soil and climatic factors may be profitably modified to suit the adaptation of the plants. It has been found that many plants can be brought under cultivation with comparative ease if the soil reaction is so modified that it approximates that of the soil in which the plants grow in nature. In the semi-arid and arid sections of the country, irrigation has made practicable the profitable production of certain crops, one instance being alfalfa. Drainage is another factor which has made possible the profitable production of crops on certain soils. Terracing of soils, especially those of the South, has aided in reducing erosion and in a great measure maintains the productivity of these soils. The ridging of some soils for such crops as cotton and corn, where the soil tends to be wet, makes the production of these crops feasible. Another practice, the reverse of ridging, is listing. This practice, which is followed in the drier sections of the country, allows the seeds to be placed nearer the soil water. The judicious use of organic matter and fertilizers is important in changing soil conditions and meeting the needs of certain crops. As an instance, cotton may be mentioned. With the increasing ravages of the boll weevil, cotton production is being extended into other sections less favorable to its production, and the climatic limitations are being partly overcome by the practice of better soil management.

Thus, by modifying to some extent the climatic factors through control of temperature, as in greenhouses, and by supplying moisture, as in the case of irrigation, the farmer can meet within limits the adaptation of plants. Also the soil requirements of the plants can likewise be modified within limits by the judicious addition of fertilizers and organic matter, by proper liming, by drainage when advisable, by terracing where practicable, by ridging when necessary and by listing when expedient.

CHAPTER VI

PLANT IMPROVEMENT

The opportunity to make a profit from plant improvement is very great. The acre yields of the various crops of the country are generally low. One of the best ways, under the control of the farmer, of increasing the yields of crops is the use of better seeds and plants. Babcock and Clausen (1918, page 442) state:

During the fifty years preceding the war, plant breeding had increased the yields of crops in Germany about 25 per cent. There were forty breeders of rye, seventeen breeders of potatoes, sixty of oats, and so on with the important crops plants.

Why Plant Improvement is Profitable.—Since the use of improved seeds and plants usually results in increased yields per acre, there is a decrease in unit cost of production with more profit to the producer and less cost to the consumer, other things being equal. The producer of improved plants or seeds may profit in two ways. First, he may sell the products at a comparatively high price; and second, he may increase his crop yields by using better plants and seeds.

The advisability of the purchase and use of improved seeds is shown by Jones (1920). The data shown in Table I indicate that the cost of seeds constitutes only a small percentage of the total crop value.

TABLE I.—COMPARISON OF COST OF SEEDS OF SOME FARM CROPS IN RELATION TO THE RETURNS

	Quantity of seed per acre, bu.	Market price per bushel, cts.	Cost of seed per acre	Average yield per acre, bu.	Value of crop per acre	Cost of seed as percentage of returns
Potatoes....	10.0	48.9	$4.89	109.5	$53.56	9.13
Wheat......	1.5	98.6	1.48	16.6	16.41	9.02
Barley......	2.0	54.3	1.09	25.8	14.00	7.79
Oats........	2.0	43.8	0.88	29.7	12.99	6.77
Rice........	2.0	92.4	1.85	34.1	31.50	5.87
Beans.......	0.5	600.0	3.00	15.0	90.00	3.33
Corn........	0.3	64.4	0.19	25.8	16.65	1.14

Modes of Reproduction.—Field crops may be divided into four classes, based upon their mode of reproduction or propagation. These classes are as follows: (1) crops that are normally self-fertilized, such as wheat, oats, barley, beans and vetches; (2) crops that are often cross-fertilized, such as corn, rye, grasses, alfalfa and root crops; (3) crops that are obligatorily cross-pollinated, such as red clover, sunflower, hemp and hops; and (4) crops that are propagated vegetatively, such as potatoes and sugar cane.

Plants that are normally self-fertilized may sometimes be cross-pollinated, as in the case of wheat (Leighty and Hutcheson, 1919). These investigators found that 40.97 per cent of cross-pollination takes place when wheat flowers were emasculated and left unprotected.

Plants often cross-pollinated may at times be self-pollinated and produce fertile seeds. However, self-fertilization in the case of cross-pollinated plants sometimes results in decreased yield and vigor. In the case of sunflowers, the self-fertilized seeds are sterile while the cross-fertilized seeds are fertile. This fact makes the improvement of sunflowers more difficult.

Why Plant Improvement Is Possible.—That "like begets like" is true in large degree but there are some exceptions. It is well known that no two plants are exactly alike; differences or variations are found everywhere. In a single variety of wheat are to be found plants that differ greatly. The difference may be in height, yield, color of seeds or some other characteristic. In a single corn variety are to be found plants differing in yielding ability, time of maturity, color of stalk and so on. In timothy some of the plants have a tendency to spread; others, to grow erect. Some are very leafy and some are very resistant to disease. In fact, in no variety of any crop does variation seem to be absent. Variations are so widespread and our knowledge of them so meager that Darwin once said: "Our ignorance of variation is profound." In fact, variation is at once the hope and despair of the plant breeder. It allows the breeder to make advances but at the same time constant attention is necessary in order to prevent an unfavorable variation from overcoming the good that has been accomplished. Thus, because of variation, plant improvement is possible by the selection, for foundation stock, of individuals which most nearly approach the type desired

Pure-line Theory.—The theory as developed by Johannsen conveys the idea that a variety is made up of a number of elementary species which can be separated out by pedigree methods. Selection isolates the elementary species from a mixed population or variety, but further selection within the isolated species is without effect, unless some heritable variation occurs. Therefore, the pure line conveys the idea of a group of plants all of which have the same constitution and will breed alike. A

pure line, then may be defined as the progeny of a single self-fertilized homozygous individual. Thus, the plants of a pure line must be self-fertilized and must breed true; that is, they must be homozygous.

Methods of Breeding.—In general there are two methods of breeding: (1) selection, and (2) hybridization followed either by direct utilization or by selection and fixation of new strains or varieties. In using these methods one should have a definite aim in mind. As a rule it is better to practice selection and isolate the best strains. If the desired individuals are not secured in this way, then individuals having certain desirable characteristics should be hybridized with the hope of combining in one individual the desirable characteristics of the parents.

The strains developed should be better than the best of the commercial sorts already developed. Therefore, before starting any breeding work, the breeder should make a careful survey of the varieties which already exist.

Selection.—This method of breeding tends to increase the proportion of individuals belonging to a particular genotype in a population; that is, to those that breed alike. Selection is valuable since practically all varieties are made up of strains which differ in certain characteristics. The object of this method of breeding is to isolate the better strains or elementary species from the variety. An *elementary species* may be defined as a small group within a botanical or horticultural variety. There are three kinds of selection: mass, pedigree and clonal.

Mass Selection.—By mass selection we mean the selection of the best individuals and the grouping or mixing together of their seeds. The seeds are planted *en masse* without any attempt to keep separate the progeny of each individual plant. This method is simpler than the pedigree system but it takes a longer time to accomplish the same result. In mass selection the poor strains are likely to be carried along with the good ones, but these poorer groups are slowly eliminated. In pedigree selection only the best strains are continued in the tests, the poorer strains being early eliminated. It is evident, therefore, that in mass selection a limit is gradually approached and this limit is that of the best strain or genotype in the population or variety. However, this limit is never absolutely reached because of the poorer strains present. In case of pedigree selection the best strains are isolated at once.

For a number of years mass selection has been practiced with good results. This method was used by Andre Leveque de Vilmorin in his selection of sugar beets for high sugar content. Rimpau used this method in making selections of rye and wheat, and developed the Schlanstedt variety of rye in this way. This method has been also used with cotton and corn.

Pedigree Selection.—In pedigree selection, individuals are selected and the seeds are planted in pedigree rows in such a manner as to

keep the progeny of each parent separate. In this way not only the form but the performance of each individual selected is known, the poorer individuals can be eliminated and the better ones carried into further trials.

The use of pedigree selection in case of self- or close-bred plants allows the breeder to make a rapid segregation of the elementary species or pure lines from a mixed population. This method has been used with cereals for a number of years. In the early part of the nineteenth century Le Conteur practiced pedigree selection. He introduced into commerce in 1830 the "Talavera de Bellevue" wheat. This same method was used about this time by Shirreff and by Hallet in the improvement of cereals. In America the method was first used by Hays in the improvement of small grains at the Minnesota Experiment Station. Hays devised what is known as the "centgener" method of grain breeding, which, in brief, is the planting of 100 grains from each selected plant in trial plats. The more promising plants were selected from the best centgener plats, planted by the centgener method in succeeding years, and the process repeated from year to year.

The pedigree selection method is now widely used in the United States in the improvement of crops, and some very valuable results have been obtained. It is applicable not only to self-fertilized plants such as wheat and oats, but to the cross-fertilized plants such as corn.

Ear-to-row Test.—This is a form of pedigree selection followed to a great extent in the improvement of corn. It consists in comparing the relative productivity of different ears of corn when planted side by side. The method as outlined by Williams (1905, 1907) of Ohio is closely followed in the discussion given here. Only a portion of each ear is planted; the remainder or remnant is saved until harvest time. The ears are planted on uniform land and are fertilized and cultivated in the same way. A row 40 hills long may be planted from each ear. Row number 1 is planted with ear number 1, row number 2 with ear number 2 and so on until all the ears to be tested are planted. It is well to use 50 to 100 ears in the test. Every tenth row should be planted with seed of a standard, adapted, commercial variety. The yields of the various ears chosen are compared with the check rows. Where practicable it is well to plant each of the ears in duplicate. At harvest time the yield of each row is obtained and compared with the yield of the check rows. Seed is not obtained from the highest yielding rows since it may be crossed with pollen from low-yielding rows, but the remnants of several of the ears which were high yielding in the test are planted the next year in a breeding plat. Therefore, the ear-to-row test serves to determine the high yielding ears and not to produce seed corn.

The breeding plat should be remote from other corn fields to prevent undesirable pollination. Rows 20 hills in length may be planted and

replicated as often as the seed may allow. The remnant of the highest yielding ear serves as the sire ear and is not detasseled, but the other remnants are called "dam ears" and are detasseled. The sire ear should be used to plant every third or fourth row; the other remnants are planted between the sire rows. When the plants begin to tassel, the plat should be visited each day and the tassels removed from the dam rows. In this way pollen will be furnished by the highest yielding ear. The yield from each ear remnant can be determined at harvest time, if from time of planting a record is kept of each ear.

The next season the ears from the detasseled rows are planted in what is known as the "multiplying plat." This is, as the name indicates, a plat where the seed of the breeding plat is increased for next year's planting, and it should be removed far enough from other corn to prevent undesirable pollination.

Head-to-Row Test.—This test is used in the pedigree selection of such crops as wheat and oats. In carrying out this test, we select a number of heads, say 50 to 1,000, from as many different plants. These heads are usually selected from the general field. The yielding ability of the different heads is determined by planting in short rows. The rows for wheat are usually about 2.5 feet long and for oats about 5 feet long. Usually about 25 to 30 seeds of wheat or 40 to 60 seeds of oats are planted to each row. Every tenth row is seeded to some high-yielding, standard variety with which to compare the head selections. A rigid selection of the strains grown in the head-to-row test results in the discarding of about 75 per cent during the first year. Each row saved is harvested and threshed separately. Such characteristics as stiffness of straw, maturity, yield and disease resistance are taken into consideration. The second year the seeds from the best head rows are planted in the so-called rod rows, a definite amount being seeded to each row and the approved rate of seeding being used for the particular grain. Every tenth row is planted with some standard variety, as in the case of the head rows. Usually two or three rod rows are seeded from each head row saved from the preceding year. The rows are harvested and threshed separately and the yields obtained. In the third year the seeds from the best rod rows are planted in rod rows replicated ten times, with every tenth row a check. The ten rows from each rod row of the preceding year may be harvested and threshed together or separately as seems most advisable. The yielding ability and other qualities of the various rod rows are studied. The procedure of the third year should be conducted for at least three years longer. If any selections are obtained superior to the check variety, they are carried to the multiplying plat to secure a supply of seed for field planting. The head-to-row test with wheat, oats and barley is less difficult to conduct than the ear-to-row test with corn, since the former are self-fertilized. Therefore, with a crop like

wheat no precaution is necessary to prevent cross-pollination as is the case with corn.

Many other specific methods of pedigree selection have been proposed by different workers, but the two methods described will illustrate that the application in detail of pedigree selection is not uniform for all plants.

Clonal Selection.—This type of selection is applied to plants propagated asexually. It consists in the selection of the clons from a mixed population or the selection and propagation of variations within clons. A *clon* or *clonal variety* may be defined as one propagated asexually, as

Fig. 2.—Showing variations in clons of orchard grass.

by cuttings, bulbs or grafts. The varieties of strawberries, apples and potatoes are examples. Here the bud rather than the seed is the unit of selection. Clonal selection is widely used in potato and sugar cane breeding, and the method is generally followed in improving some kinds of grasses.

Hybridization.—This method of breeding tends to change the type altogether by the introduction of new factors. Through the recombination of factors, strains having desirable characters are often recovered. In addition to the recombination of factors hybridization often increases vigor, at least temporarily.

The individual resulting from crossing contains factors of both parents and is called a "hybrid." A *hybrid* group may be defined as the progeny resulting from a cross-fertilization of parents belonging to different strains, varieties, species or genera. Many hybrids have proved to be valuable additions and a number of specific instances might be cited. The behavior of many characters in hybridizing has been studied. Individuals have been studied in regard to stature, earliness, yield, vigor, resistance to drought, resistance to disease, winter hardiness, presence or

absence of awns and so on. These characters have been found to act in certain definite ways. It is difficult to estimate the value of hybridization.

Not only does the hybrid differ in constitution from either parent but it is usually more vigorous than either one. With the increased vigor are often found resistance to disease, better adaptation to environment, greater vitality of seeds, hastening of the blooming period and earlier maturity.

Principles Involved in Breeding Crops.—The principles involved in breeding crops that are self-fertilized, cross-fertilized or propagated asexually vary to some extent. The details of the methods will vary for the different crops within a group, but the principles involved for a particular group will hold for all plants within that group.

FIG. 3.—Each row represents a different inbred strain of the same variety of corn. Note the marked difference in vigor.

Self-fertilized Crops.—In crops of this kind the pedigrees are either pure or rapidly becoming so. The principles involved in such crops are as follows: (1) A selection is made of types which are already present; (2) the initial selection is everything; nothing new is added to the strain after the first selection; (3) tests are made of the different strains isolated to determine their relative value; and (4) after the selection has been isolated, further selection within the strain is of no avail.

Cross-fertilized Crops.—Corn will be used to illustrate the principles involved in breeding these crops. The principles are as follows: (1) Corn is naturally cross-fertilized, owing to the existence of a large number of elementary species within any variety and their tendency to cross-pollina-

tion. The natural crossing of these species or any variety of corn is likely to produce a hybrid complex for many factors. (2) Selection accompanied by inbreeding results in a gradual reduction to a homozygous or pure condition, the same purpose being accomplished by isolation of strains. In this way elementary species are isolated. (3) Inbreeding, as a rule, has harmful effects in case of corn. (4) Cross-breeding usually increases the vigor of corn. Inbred strains when crossed give greater vigor than that which results from crossing the varieties before inbreeding. (5) The pure-line method cannot be practiced successfully with corn since the homozygous forms are of little value commercially. (6) Any successful method of corn breeding must provide for the natural crossing of different elementary strains within the variety.

Asexually Propagated Crops.—The principles involved are as follows: (1) In asexual propagation a portion of the body-plasm is passed to the next generation. There is, therefore, a very close resemblance between offspring and parent. (2) Since no reduction-division takes place, there is no chance of segregation or recombination of factors. Strains breed true even though they are actually hybrid. (3) Theoretically, selection within such a strain should yield no results since all members of a strain are of the same genetic constitution—a vegetative pure line. (4) Variation within such a group may be of the following nature: (*a*) fluctuations which are not inherited but which are capable of exerting a certain temporary influence through effect on nutrition; (*b*) environmental modifications which are of such a nature as to be more or less permanently impressed upon the body-plasm; (*c*) bud mutation, that is, any variation having its origin in a single bud. If the bud mutation is wide, it will give rise to a new variety; but if it is slight, it may give rise to a new elementary species, provided the mutation is of the right sort. (5) If selection within a variety which is propagated vegetatively is effective, one of the following changes has taken place: either (*a*) transmission of body modification, or (*b*) occurrence of bud mutation or variation. (6) Selection within varieties propagated asexually has been found effective in many cases. A single branch of an orange tree may bear superior fruit and the wood of the branch is valuable for propagating a new strain of the variety.

Some Accomplishments in Plant Improvement.—Mention is made in Chapter VII of some of the well-known varieties and a brief statement given as to their value and mode of origin. Many other instances could be cited of improvement in plants.

Improvement by Selection.—The comparative yields of some selections of wheat and oats and the commercial varieties from which the selections were made are reported by Love and Craig (1918), and shown in Table II.

Columbia cotton was a mutation found in the Russel Big Boll variety. This variety was developed from an individual plant differing from the ,arepnt variety, especially in having longer lint.

II.—Three-year Average Yields in Bushels per Acre of Oat and /heat Varieties and Selections, with the Increases Obtained

Variety and selection	Oats 3-yr. average yield per acre, bu.	Gain, bu.
Cluster	56.9	
Cluster 110–36	65.6	8.7
	53.2	
109–14	57.4	4.2
109–15	58.4	5.2
r	52.4	
r 115–27	58.3	5.9
r 115–40	57.9	5.5
ale	50.2	
ale 114–2	56.7	6.5
ale 114–4	57.1	6.9
ale 114–14	57.8	7.6
ale 114–16	58.0	7.8
	Wheat	
:e	28.2	
:e 126–26	30.4	2.2
:e 126–44	31.3	3.1
r	26.0	
r 123–23	27.9	1.9
r 123–32 (beardless)	30.2	4.2
ve	27.7	
ve 128–47	31.1	3.4

the Kentucky Experiment Station, Valleau and Kinney (1922) leveloped, through selection, strains of Standup White Burley) resistant to root rot. Not only are these improved strains resis- root rot but they also give a product of good quality, of earlier ty and possessing greater uniformity of growth than the parent .

provement by Hybridization.—Hybridization as well as selection has many important improvements in crop plants. Much work has one in crossing corn. In many instances, increases in yield are :he year the cross is made, but the increases in the following year en still greater.

: yield from corn crosses in the first hybrid generation as com- with the parents may be illustrated by results secured at the a Experiment Station.

TABLE III.—PERCENTAGE OF INCREASE OR DECREASE IN YIELD OF CORN HYBRIDS AS COMPARED WITH YIELDS OF THE PARENTS (AVERAGE 1916 AND 1917)

Hybrid	Increase or decrease as compared with		Average, per cent
	Seed parent, per cent	Pollen parent, per cent	
Shenandoah County White × Gold Standard	69.25	−1.52	33.87
Boone County White ×[1] Gold Standard	27.94	5.08	16.51
Johnson County White × Gold Standard	32.06	8.57	20.32
Shenandoah County White ×[1] Reid's Yellow Dent	134.14	21.47	77.81
Boone County White × Reid's Yellow Dent	15.95	−7.52	4.22
Johnson County White × Reid's Yellow Dent	25.05	−2.51	11.27

[1] Data for 1917 only.

The hybrids Boone County White × Gold Standard, Shenandoah County White × Reid's Yellow Dent, and Johnson County White × Gold Standard yielded a great deal more than their parents. However, the results for the first two hybrids are for only one year. The hybrid Johnson County White × Gold Standard not only yielded more than either parent but matured 5 days before the earlier parent and had 2.02 per cent more matured ears than the pollen parent and 14.31 per cent more than the seed parent.

In the cereals numerous varieties have been developed by hybridization. Fulcaster wheat, a bearded, semi-hard, red wheat, widely grown in the eastern part of the United States resulted from a cross between Fultz and Lancaster. Marquis, a spring wheat, grown to a great extent in the Middle West, was obtained by crossing Hard Red Calcutta with Red Fife. At Svalöf, Sweden, a wheat hybrid Extra Square Head II was obtained by crossing Extra Square Head with Grenadier II. The cross contains the hardiness and disease resistance of the former with the high yielding capacity and stiff straw of the latter.

The Connecticut Round Tip tobacco was secured by selection from plants obtained by crossing the Sumatra and Broadleaf varieties. The hybrid, which has been tested for ten years, has an especially well-developed root system, a compact, rounded leaf, develops a large number of leaves and is apparently very resistant to root rot.

RELATIVE IMPORTANCE AND LIMITATIONS OF PLANT IMPROVEMENT

Importance.—It is difficult to estimate the value resulting from the improvement of crops. A small degree of improvement is of much impor-

tance when we consider the enormous acreage that is covered by some of the staple crops. In the United States about 100,000,000 acres of land each year is planted to corn which means 1 acre of corn for each individual of our population. Think what the increase in yield of corn would be in sum total should all this land be planted with an improved variety of corn yielding 1 bushel more to the acre than that which is now planted. There is room for improvement of the wheat crop, the oat crop and, in fact, all the crops we now grow. Any variety tests show great differences in yielding ability and other characteristics of the varieties used and show that in order to secure the largest yields, the best plants must be used.

Limitations.—Plant improvement, although necessary for maximum production of crops, has its limitations. Usually the degree of improvement secured is small; however, this is not always the case. It is to be remembered that, even though the degree is small, the amount is large in the aggregate. In order to secure material improvement of crop plants much time and painstaking labor are required. After improvement has been achieved, it is necessary to continue to use a certain amount of care in maintaining the new standard attained. It is often difficult to impress upon the farmer the value of continued selection, prevention of mixtures, treatment for diseases and other precautions to maintain the highest quality. Too often valuable additions to agricultural plants are lost because of the careless attitude of the farmer and his failure to realize their importance.

In the head-to-row test with small grains six or seven years are required before the definite behavior of any one of the original individual selections is determined. When the behavior has once been determined, several additional years are required to secure sufficient seed for extensive planting. In hybridization work, numerous crosses are frequently made and a large amount of selection done before a desirable type is obtained.

When all the limitations are taken into consideration, plant improvement still remains a highly profitable undertaking for the organizations and individuals interested in such work. The truth of this statement is easily shown; for a single improved plant means a step forward to agriculture and a definite gain to the people as a whole. It is difficult to estimate the value of the Boone County White variety of corn to the corn growers, Marquis wheat to the wheat growers of the West, early maturing varieties of cotton to the cotton growers of the boll weevil infested areas, Fulcaster wheat to the eastern wheat producers and the Burbank potatoes to the potato growers.

Plant Improvement under Farm Conditions.—Much valuable work has been done by farmers in the improvement of plants. The work of Riley in the development of Boone County White corn, of Reid with Reid's Yellow Dent corn, and of Leaming with the Leaming variety is well

known. Many progressive farmers practice selection in the improvement of the field crops they grow. In several states, crop improvement associations have been organized, the results obtained in Michigan, Wisconsin and Virginia being especially noteworthy.

Mass selection seems to be the most practicable method for farmers to follow in improving field crops. This method may be easily followed and excellent results accomplished with wheat, oats, corn, barley, potatoes and, in fact, with practically all field crops. Some farmers follow the ear-to-row system of breeding corn. A farmer in Virginia planted 52 ears of Boone County White corn in an ear-to-row test. The 4 highest yielding ears yielded, on the average, 80.2 bushels and the remaining 48 yielded, on the average, 68.2 bushels. This increase of 12 bushels is well worth while.

Many farmers practice roguing of their crops; that is, removing admixtures. This practice is especially valuable in the case of small grain crops. Rye is often found mixed with wheat, vetch with oats and rye, and barley with oats. It is not unusual to see smooth wheat badly mixed with bearded varieties, and vice versa. All such admixtures should be removed. In addition, the best types of a variety should be propagated for planting in succeeding years. Better care of seed will go a long way in preventing varieties from "running out."

That farmers can maintain and improve the quality of their crops in many respects, is evidenced by the results that have been accomplished by a few progressive groups in various sections of the country.

CHAPTER VII

THE VALUE OF GOOD VARIETIES

Of the factors in crop production under control of the farmer, there is nothing of more importance than the choice of high-yielding adapted varieties. Even though all conditions for growth may be most favorable, the yield will not be so good if a poor variety is used.

Requirements of a Good Variety.—In the choice of the variety there are several things to be taken into consideration. They are as follows:

1. Adaptability.
2. Yielding ability.
3. Purity.
4. Quality of product for market or feeding purposes.
5. Winter hardiness.
6. Strength of straw or stalk.
7. Ability to resist disease.

Adaptability.—It is of first importance that the variety be adapted to the section in which it is to be grown. Even when highly advertised, a variety may be absolutely worthless under practically all conditions. On the other hand, a variety may be excellent under some conditions but inferior under other conditions. This point may be illustrated by using the Kanred variety of wheat, which is an exceptionally good one for certain sections of the West. However, in Virginia in 1921 it yielded 8.25 bushels to the acre, while Fulcaster yielded 17 bushels. Therefore, the fact that a variety yields well in one region is no guarantee that it will necessarily yield well in another region. The same variety, however, may do well in two widely separated regions. In 1915 the Virginia Experiment Station introduced Silver King (Wisconsin No. 7) corn into Virginia from Wisconsin. It yielded exceptionally well the first year and has done so ever since. The choice of the right variety, therefore, requires careful study.

Adaptation to Soil.—The lack of adaptation may be due to a soil or to a climatic condition or both. It is well known that some varieties do well on some soils but not on others. Under Virginia conditions on the light-colored soils of the eastern parts of the state the smooth varieties of wheat outyield the bearded varieties. However, on the heavier, dark-colored soils the bearded varieties yield better than the smooth varieties. Thus Fultz, a smooth-headed variety, is widely planted in the eastern section.

Cunningham and Wilson (1921) in Kansas found that the earliest and smallest varieties of corn yielded best on poor soils, while on the rich soils the large varieties produce the largest yields. The results are shown in Table IV.

TABLE IV.—RELATION OF PRODUCTIVENESS OF THE SOIL TO YIELD OF LARGE, MEDIUM AND SMALL VARIETIES OF CORN IN KANSAS

Variety	Number of days to mature	Yield in bu. per acre					
		1914		1915		1916	
		Poor soil	Prodt. soil	Poor soil	Prodt. soil	Poor soil	Prodt. soil
Hildreth Yellow Dent...	135	26.3	47.8	22.6	52.5	8.2	28.7
Commercial White......	125	37.0	59.6	28.3	51.1	12.2	41.0
Pride of Saline.........	115	39.8	55.0	30.4	48.0	16.6	41.3
Freed White Dent......	105	36.6	53.8	35.9	41.2	23.1	35.4

Mooers (1922) in Tennessee has shown that varieties of corn behave differently on soils of unlike degrees of productivity. Leaming yielded less than Hickory King under all degrees of productivity; but as the productivity increased, the difference in yield became greater. It was also demonstrated that on land producing up to about 28 bushels of corn per acre, Albemarle yielded less than Hickory King, but on land producing more than 28 bushels the reverse was the case.

Adaptation to Climate.—Climatic conditions greatly affect the choice of the variety. It seems that some varieties are adapted to certain climatic conditions but not to others.

The relative yield of varieties of corn has been found to vary with rainfall. In Kansas, Cunningham and Wilson (1921) found that the early-maturing varieties yielded better under conditions of limited soil moisture, while the later maturing varieties yielded highest when the moisture supply was plentiful. These data are presented in Table V. In central and western Kansas rainfall is the limiting factor, while in the eastern portion of the state, rainfall is more abundant.

TABLE V.—EFFECT OF ANNUAL PRECIPITATION ON THE YIELDS OF LARGE, MEDIUM AND SMALL VARIETIES OF CORN IN KANSAS

Variety	Number of days to mature	Average yield in bu. per acre		
		Eastern Kansas	West Central Kansas	Western Kansas
Kansas Sunflower.............	125	44.3	20.1	10.1
Pride of Saline...............	115	42.1	21.8	13.3
Freed White Dent............	105	38.8	27.2	18.5

The effect of drought is well shown by results secured in Kansas. In 1914 the season was favorable until midsummer when drought occurred. In 1915 the conditions for growth were favorable throughout the growing season, while in 1916 drought started about the middle of June. The results are shown in Table VI.

TABLE VI.—EFFECT OF SEASONAL CONDITIONS ON YIELD OF LATE, MEDIUM AND EARLY VARIETIES OF CORN IN KANSAS

Variety	Number of days to mature	Average yield in bu. per acre		
		1914	1915	1916
Hildreth Yellow Dent	135	39.1	55.0	12.1
Commercial White	125	47.7	49.9	14.4
Pride of Saline	115	51.0	52.6	18.5
Freed White Dent	105	48.9	45.2	23.3
Sherrod White Dent	95	....	36.4	26.2

Length of Growing Season.—The length of the growing season has a marked effect on yield. A corn that matures in 150 days will yield more than one which matures in 125 days, other things being equal. The growing period should be long enough for the corn to utilize the entire season favorable for its development. In Kansas, Pride of the North, an early variety, yielded 7.3 bushels per acre less than Kansas Sunflower, a late variety.

Yielding Ability.—It has been shown that before maximum yields can be obtained a variety must be adapted to the section in which it is to be grown. There is a great variation in the yielding ability of different varieties when grown under the same conditions and given the same methods of culture. The yielding capacity of varieties can best be determined by the study of results of variety tests conducted by experiment stations. Since varieties are often adapted to rather limited areas, the results of tests conducted in a neighboring section are likely to be more reliable than those secured in some remote section.

The difference in the yielding ability of red clover from different sources is shown by Wiggans (1921*a*) in New York. The dry weight of clover per acre for Michigan-grown seed was 6,635 pounds; from French-grown seed, 5,966 pounds; and from Italian seed, 334 pounds.

Ayres (1921) in Mississippi reports the average value of seed and lint of different varieties of cotton during the 10-year period, 1911 to 1920, as follows: Express, $140.72; Foster, $134.40; Wannamaker-Cleveland, $126.44; Lone Star, $126.02; Webber, $125.60; Trice, $118.80; Sunflower,

$117.20; Columbia, $114.16; Triumph, $113.60; Miller, $111.98, and Cleveland Big Boll, $110.06.

Jardine (1917) reports the 6-year average acre yield of three varieties of wheat grown at Manhattan, Kansas, as follows: Kanred, 31.1; Turkey, 26.5; and Kharkof, 25.9 bushels per acre.

The 5-year average acre yield of certain varieties of wheat at the Virginia Experiment Station was as follows: Egyptian, 19.76; Dietz Amber, 19.64; Fulcaster, 19.17; Fultz, 18.81; Blue Straw Fultz, 14.98; and Leap's Prolific, 14.75 bushels per acre.

At the Virginia Experiment Station the 6-year average acre yield of several varieties of rye was as follows: Giant Winter, 29.73; Common Winter, 26.86; Dean, 24.52; Abruzzi, 22.25; and Von Rümker C. I. No. 173, 20.11 bushels per acre.

The average yield of soybeans, hay and seed, in Virginia is shown in Table VII.

TABLE VII.—RESULTS OF VARIETY TEST OF SOYBEANS AT THE VIRGINIA EXPERIMENT STATION

Variety	Yield per acre—average of 6 seasons	
	Hay, tons	Seed, bu.
Haberlandt	2.90	27.25
Mongol	1.89	24.58
Austin	3.14	23.22
Hollybrook	2.18	21.52
Virginia	1.80	21.16
Sable	1.76	15.28
Chiquita	2.72	14.92
Medium Black	0.98	11.22

The results of variety tests with crops could be given almost without limit. However, the illustrations given will serve to show that there is a marked difference in the yielding ability of varieties.

Purity.—A pure variety is usually more desirable than a mixed variety. However, in some instances it has been found that a mixture of varieties will yield more than the same varieties when grown alone.

Quality.—The quality of the crop produced may be as important or more important than the quantity produced. It is desirable to produce wheat with a high milling quality, oats with a low percentage of hull, corn with a high percentage of grain to stalk, cotton with long fiber, peanuts with a low percentage of hull and potatoes with the qualities necessary

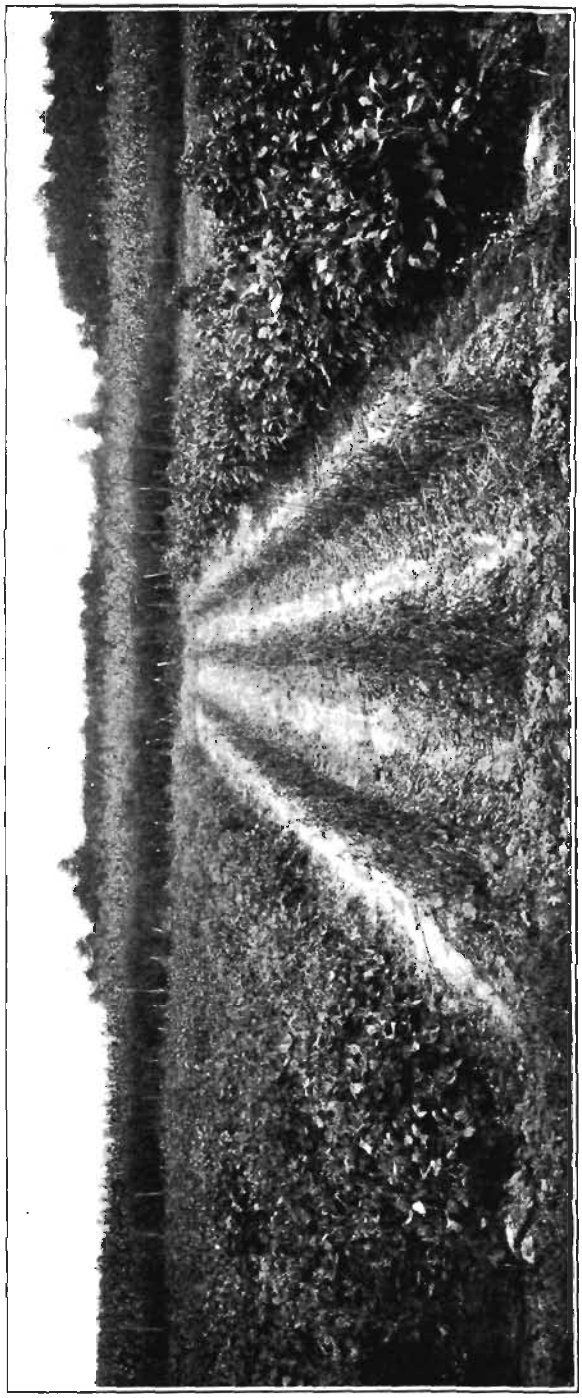

Fig. 4.—Variety test of soybeans. Note differences in degree of maturation.

for cooking purposes. Varieties differ greatly in respect to quality. Some differences may be shown by specific examples.

Jardine (1917) in Kansas compared Kanred wheat with the Turkey and Kharkof varieties. In regard to the milling and baking tests, the results show "a distinctly higher protein content, both in the wheat and in the flour, of Kanred than of Turkey and Kharkof; a higher percentage of flour than Kharkof, but somewhat less than Turkey; a loaf expansion practically equal to Kharkof and slightly greater than Turkey; color of loaf equal to or better than either of the standard varieties; and texture of loaf equal or superior to either of the other varieties. The amount of dry and wet gluten is also distinctly in favor of the new variety." Varieties of wheat often differ greatly in milling and baking quality.

Ball and Clark (1916) state that Marquis wheat is equal or slightly superior in milling and baking quality to samples of Fife, Bluestem and Preston (Velvet Chaff) wheats grown under similar conditions.

Love (1913) at Cornell University found that varieties of oats differ in percentage of meat. An oat with a high percentage of meat is desirable. The percentage of meat in the Lincoln variety was 71.06; in the Welcome, 69.41; in the Swedish Select, 66.54; in Long's White Tartar, 70.43; in Storm King, 58.23; in Mortgage Lifter, 68.98; and in Twentieth Century, 69.14.

Corn varieties differ in the marketability of corn produced. The Virginia Experiment Station results show that the percentage of marketable corn varied from 61.54 to 79.47 per cent. These results, based on four seasons, are given in Table VIII.

TABLE VIII.—YIELD AND PERCENTAGE OF MARKETABLE GRAIN OF DIFFERENT VARIETIES OF CORN AT THE VIRGINIA EXPERIMENT STATION

Variety	Yield in bu. per acre	Percentage of marketable grain
Silver King	44.96	79.47
Reid's Yellow Dent	51.55	78.55
Boone County White	51.08	76.71
Hickory King	42.90	76.52
Shenandoah County White	48.56	75.85
Leaming	49.91	74.38
Gold Standard	42.64	67.22
Cocke's Prolific	36.11	66.09
Virginia Ensilage	41.06	61.54

In the choice of the variety the quality should be taken into consideration as well as the yield. The examples that have just been discussed should show the importance of this recommendation.

Winter Hardiness.—Varieties of crops are affected to different degrees by the severity of the winter. Some varieties can endure winter cold, while others are greatly injured by it. A variety that winter-kills badly does not yield well. No doubt many varieties hold a high rank chiefly because of their resistance to winter-killing. The production of cold-

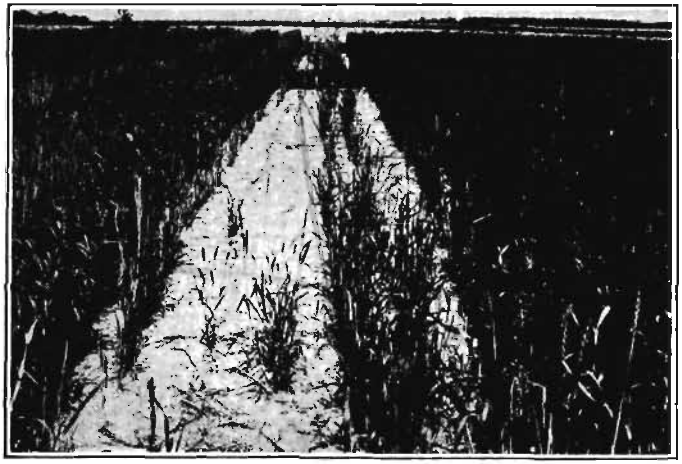

Fig. 5.—Varieties vary in their resistance to cold. Each row represents a different variety of wheat planted on the same day. Those in the center were badly winter-killed.

resistant strains of wheat has meant much to the growers in the more northerly section of the main wheat growing regions. Winter wheats, where they grow well, are preferred to spring wheats, since they allow a better distribution of labor, mature earlier and yield more grain per acre.

The variation in susceptibility of wheat to winter-killing is shown by Hayes and Garber (1919). Their results are shown in Table IX.

Table IX.—Yield and Hardiness Test of Wheat in Minnesota

Variety	Average yield in bu. per acre, 1916–18	Average winter injury, per cent
Odessa	31.1	38
Turkey	36.8	40
Turkey × Odessa	39.1	29
Turkey × Odessa	34.9	42
(?) × Turkey	38.7	
Crimean	30.6	37
Turkey	23.0	73

Kanota, an oat developed by the Kansas Experiment Station, is resistant to the late spring freezes; Red Rock wheat, developed at the Michi-

gan Experiment Station, is exceptionally winter hardy; and this same characteristic is reported for Kanred wheat.

Alfalfa varieties differ greatly in their winter hardiness. The more hardy varieties are Grimm, Baltic and Canada Variegated. The less hardy varieties are Peruvian and Arabian. Wiggans (1921*a*) at Cornell University found in the case of red clover that 90 per cent of the plants from Michigan-grown seeds lived through the first winter, 80 per cent from the French-grown, and only 5 per cent of the plants from the Italian-grown seeds.

Strength of Straw and Stalk.—Varieties of small grains differ widely in their tendency to lodge. For the greatest yield it is necessary to choose varieties that stand erect. Stiffness of straw is especially important on rich land where there is more tendency to lodge than on poor soils.

Ability to Resist Disease.—In order to secure the best yields it is highly desirable that plants be free from disease. Varieties vary greatly in their ability to resist certain diseases. Fromme (1921) in Virginia found Leap's Prolific wheat to be very resistant to loose smut, while Stoner was very susceptible. On the average, bearded varieties were three times as susceptible as beardless varieties. Australian wheats grown in this country were found to be susceptible to black stem rust (*Puccinia graminis*), to the yellow stripe rust (*Puccinia glumarum*) and to the leaf rust (*Puccinia triticina*). They are also susceptible to bunt or stinking smut (*Tilletia foetens* and *Tilletia tritici*) (Clark and others, 1920). Kanred wheat is resistant to both stem and leaf rusts.

The difference in susceptibility of wheat to bunt or stinking smut as reported by Gaines (1920) is given in Table X.

TABLE X.—PERCENTAGE OF INFECTED PLANTS, PERCENTAGE OF BUNT ON INFECTED PLANTS AND TOTAL PERCENTAGE OF LOSS FROM BUNT IN 1918 OF THE THREE PARENTS AND F_2 AND F_3 GENERATIONS OF TURKEY × HYBRID 128 AND TURKEY × FLORENCE. WASHINGTON EXPERIMENT STATION

Variety or hybrid	Infected plants, per cent	Bunted heads on infected plants, per cent	Total bunt produced, per cent	Number of rows	Average number heads per plat
Turkey	3.4	17.7	0.6	6	13.6
Hybrid 128	70.9	63.9	59.8	3	13.7
Florence	5.8	22.9	1.3	3	9.6
Turkey × Hybrid 128 F_2	76.4	47.9	51.0	3	13.9
Turkey × Florence F_2	20.1	35.5	8.9	2	16.7
Turkey × Hybrid 128 F_3	68.3	49.1	50.2	194	13.0
Turkey × Florence F_3	22.1	45.5	15.4	168	16.3

In the case of timothy some of the Cornell selections seem to be very resistant to rust. The selections developed at the Minnesota Experiment Station, however, are very susceptible, while at the Arlington Farm in Virginia the selections made there have not been found resistant.

Value of Some Famous Varieties.—It is difficult to estimate the importance and value of the leading varieties of the different crops. It is not unusual, however, to find different varieties varying greatly in yields even when grown under similar conditions. Some of the well-known varieties of crops will be discussed.

Kanred Wheat.—The introduction of hard winter wheats from Russia into Kansas and other states of the central Great Plains area changed wheat growing in that region, and wheat production bids fair to be stimulated still further by the development of the variety of wheat known as Kanred. It is a selection of the well-known Turkey type of hard winter wheat.

Marquis Wheat.—This is a hard spring wheat which Saunders (1912) developed by crossing an early ripening Indian wheat, Hard Red Calcutta, with Red Fife. A strain with high bread making strength and good color of flour was selected from the descendants of this cross. This strain was named Marquis and its value to agriculture is very great. Among its advantages it numbers early ripening tendency, a quality which allows it to escape rust; stiffness of straw; heavy weight per bushel; good appearance of grain; and high milling and baking quality. Clark (1920) states in regard to this wheat as follows: "In 1914 it made up about three per cent of the wheat acreage of Minnesota and the Dakotas. Since that time this variety has increased rapidly in popularity, and in 1919, only seven years after being introduced, it made up about sixty per cent of the total spring-wheat acreage."

Red Rock Wheat and Rosen Rye.—Red Rock wheat, Spragg (1918), was developed at the Michigan Experiment Station. This variety came from an individual kernel picked out of Plymouth Rock, a white wheat. Red Rock wheat is very winter hardy, has exceptionally stiff straw, yields well, and has superior milling and baking qualities. The seeds were first distributed to farmers in 1913, and in 1917 there were about 4,000 acres of land seeded to this variety in Michigan. In 1918 about 100,000 acres of land were sown to this variety.

Rosen rye, Spragg (1918), was first distributed by the Michigan Experiment Station in 1912. Because of its high yielding ability and other desirable characteristics this variety has spread rapidly, and it is estimated that 15,000 acres were grown in Michigan in 1917, while 250,000 acres of land were sown to this variety in 1918. It is stated that Rosen rye has caused Michigan to rise from the fourth or fifth place to first place in rye production in the United States.

Corn.—Owing to greater production from the use of improved varieties, the value of the corn crop has been greatly increased. Such well-

known varieties as Leaming, Reid's Yellow Dent and Boone County White are grown over large areas. These are high-yielding varieties, developed by years of careful selection and they have been of untold benefit to agriculture in the United States.

Range of Varietal Form in Important Crops.—There is great diversity in the varietal characters of the different field crops. In fact, the adaptation of the same crops to such diverse conditions of soil and climate is due to the great variations present. Since the varieties of the same crop vary so greatly, the farmer is able to secure one or more strains of certain crops that will fit his peculiar conditions.

Corn.—Corn, which is very widely grown in the United States, differs greatly according to the type or variety; and there exist great differences between the types or varieties grown in the various sections. In the North are to be found the early-maturing flint varieties. The grain is hard, the plants show a great tendency to tiller and each stalk often produces many ears. In the South the late-maturing, prolific dent varieties are grown which produce several ears to the stalk and the stalks often grow to a comparatively great height. On the rich soils of the river bottoms and deltas of the South, plants 15 to 20 feet in height are by no means uncommon. There are corns especially suited to droughty conditions, because of peculiar forms and habits of growth. The squaw or soft corn of the Indians, which shows a great variation in color, is a distinct type from the dent and flint groups. In any group there is a variation in color of the grain, and the white and yellow corns of the dent group are well known.

Wheat.—Wheat presents wide differences between varieties and groups. The spring wheats are distinct from the winter wheats. There is a great difference in the hardness of grain. There are to be found the hard winter, hard spring, soft or semi-hard winter and soft or semi-hard spring wheats. The grains vary as to color, some being amber, others red and still others white. The varieties differ greatly in time of maturity and in yielding ability. Some varieties have a tendency to lodge, some to shatter their grain on ripening and some to tiller to a large degree. In case of some other varieties, the reverse is true.

Oats.—In the case of oats are to be found winter and spring forms, which differ in grain color, winter hardiness, ability to yield, time of maturity, character of panicle, type of early growth, resistance to disease, and other characteristics.

Cotton.—The varieties of cotton differ in many characteristics. There are the long-staple and the short-staple groups. There is often a difference in length of staple between varieties of the same group. Differences between varieties in regard to time of maturity and resistance to disease are well known. The use of early-maturing varieties allows the cotton growers to escape the boll weevil to some degree. The wilt-resistant varieties are less injured by the cotton wilt than other varieties.

Barley.—The varieties of barley show differences no less striking than those of other cereals. The two-row and six-row groups are distinct. Great differences in yielding ability and disease resistance between varieties occur. Spring and winter forms are well known.

Varietal Distinctions.—There are certain characters used in the classification and identification of crops. Some of these characters are constant, while others are more or less variable. In the classification of varieties those characters are desirable that remain constant for a given variety. However, the more or less unstable characters are often of value in connection with the stable ones. In classification distinctions are presented under two heads: *morphological* and *physiological.*

Morphological Distinctions.—These distinctions are based upon structural differences, and many of them are practically invariable, while others are greatly affected by environment. The characteristics of the barley spikes vary greatly but their variations are usually constant under different environmental conditions. Under this head may be mentioned such characters as fertility, density, rachis and various characteristics of the spikelet, such as the caryopsis, glumes and rachilla. Such characters as color, shape, size of leaves, number and size of culms, composition, size, shape and color of the grain are influenced by environment, and are, therefore, not extremely valuable for classification studies.

Physiological Distinctions.—Physiological distinctions are based upon functional differences. These distinctions may be divided into *permanent* variations and *place* variations. Some physiological distinctions are so marked that they may always be seen. Their environment does not hide them and they may be classed as *permanent* physiological distinctions. On the other hand, when distinctions become evident only under certain conditions of soil and climate, they may be classified as *place* physiological distinctions. The physiological distinctions are important in classification work but they are often less accurately measured or determined than the morphological differentiations.

Among the physiological distinctions may be mentioned productivity or yielding ability. This may be classed either as a permanent variation or a place variation. It is greatly affected by environment, but some varieties yield more than others under practically all conditions. The rate of development, another physiological distinction, has been divided by Harlan (1914) into three periods for barley. These periods are: (1) the early development from germination to the time of jointing; (2) the period of heading; and (3) the period of maturation. These periods are greatly influenced by environment, but the difference in time of maturity of some varieties is well marked. Varieties of corn often differ as much as three weeks in time of maturity. No influence exerted by environment is likely to overcome this difference entirely.

Stability of Varietal Distinctions.—Some of the varietal distinctions are stable, little affected by environmental influences. On the other hand, some of the distinctions are comparatively unstable, and are influenced to a great degree by climatic and soil conditions. A variety may also lose its identity or appear unstable or inconstant, owing to mechanical mixtures.

Of the stable varietal distinctions of barley may be mentioned fertility, density, rachis, caryopsis, glumes and the rachilla. Etheridge (1916) considers the habit of early growth of oats as distinctive and constant; and this habit is easily determined, especially about the tillering period.

Etheridge (1916) cites references to show that the production of double grains in oats and the number of spikelets per panicle may be influenced by environment. The number of grains per spikelet may also vary. Moreover, the color of the glumes, time of maturity and physical characteristics of the oat grains seem to be influenced by environment. It is well known that environment affects the height of plants, dimensions of leaves and similar characteristics.

Influence of Environment.—The length of culms of barley is greatly affected by soil and by climate (Harlan, 1914). A selection of Odessa barley when grown in Minnesota was short and unpromising; in California it was but little better, but in the North Rocky Mountains and Plains, however, it was very tall, and exhibited unusual vigor. Abyssinian varieties of barley grew tall in California, but grew short in other places. The influence of geographical location on height of barley is shown in Table XI.

TABLE XI.—INFLUENCE OF GEOGRAPHICAL LOCATION ON THE LENGTH OF CULM IN 13 REPRESENTATIVE SELECTIONS OF BARLEY GROWN AT 4 WIDELY SEPARATED POINTS, THE SELECTIONS BEING ARRANGED IN THE ORDER OF THEIR HEIGHT AT EACH POINT

St. Paul, Minn.	Williston, N. D.	Moccasin, Mont.	Chico, Cal.
Hordeum vulgare	Servian	Odessa	S. P. I. No. 20375
Oderbrucker	Odessa	Hordeum vulgare	Oderbrucker
Manchuria	Hordeum vulgare	Surprise	Abyssinian
Summit	Smyrna	Summit	Servian
Princess	Oderbrucker	Servian	Smyrna
Surprise	Manchuria	S. P. I. No. 20375	Manchuria
Servian	Summit	Kitzing, 6-rowed	Summit
S. P. I. No. 20375	Surprise	Manchuria	Odessa
Kitzing, 2-rowed	Kitzing, 6-rowed	Oderbrucker	Kitzing, 6-rowed
Kitzing, 6-rowed	S. P. I. No. 20375	Smyrna	Princess
Abyssinian	Princess	Abyssinian	Kitzing, 2-rowed
Smyrna	Abyssinian	Kitzing, 2-rowed	Surprise
Odessa	Kitzing, 2-rowed	Princess	Hordeum vulgare

The number of culms per plant is greatly influenced by environment (Harlan, 1914). A number of 6-row barleys, when planted at St. Paul, Minnesota, averaged 2.6 culms per plant, while at Chico, California, the same selections averaged only 1.5. On the other hand, a 2-row group averaged only 4.2 culms at St. Paul, while at Chico the average was 5.8. It is interesting to find that the same variety, Smyrna, stood near the top in both cases. The effect of environment does not conceal the varietal characteristics.

The effect of environment on the composition of the barley grain is well shown by the data in Table XII from Wiggan (1921) after LeClerc and Wahl.

Table XII.—Influence of Environment on the Chemical Composition and Weight of Grain in Barley

Variety and state	Water, per cent	Fat, per cent	Fiber, per cent	Starch, per cent	Protein, per cent	Hulls, per cent	Wt. of 1,000 grains, grams	Ash, per cent
Bay Brewing, California..	8.23	2.06	6.72	58.23	9.77	14.46	35.82	3.03
Kansas..................	10.32	2.02	7.31	59.66	13.69	15.00	30.56	3.41
Two-rowed, California...	8.82	2.15	5.52	60.38	10.66	11.08	35.28	2.72
Kansas..................	10.00	2.23	5.38	55.91	17.69	11.70	35.07	3.13

Davidson and LeClerc (1917) found that nitrate of soda when applied in the early stages of growth of the wheat plant caused an increase in the protein content of the kernel. The application of nitrate of soda to the soil as late as the milk stage of the plant had no effect on the protein content of the kernel.

Effect of Spacing.—Harlan (1914) also shows that spacing has a marked influence on the tillering of barley; some varieties make better use of soil than others. The variety, Smyrna, seems to be less influenced by spacing than the variety, Manchuria. The data in Table XIII are taken from Harlan (1914).

Table XIII.—Effect of Interval on the Production of Culms in Selections of Smyrna and Manchuria Barley

Plants and culms	Space between plants					
	4 by 8 in.		4 by 4 in.		4 by 2 in.	
	Manchuria	Smyrna	Manchuria	Smyrna	Manchuria	Smyrna
Total plants...........	42	46	87	80	179	190
Total culms............	122	282	234	361	236	446
Culms per plant........	2.9	6.1	2.7	4.5	1.3	2.3

Influence of Mixtures.—Varieties are often said to "run out." This may be due to the fact that other varieties have "run in" or that the varieties have lost their identity through mechanical mixture or lack of selection. With all varieties of crops it is well to practice selection to maintain the standard of the variety. In numerous instances varieties have become so badly mixed as to be no longer recognizable.

Everyone who has lived on the farm has seen beardless wheat plants present in fields of bearded wheat, and vice versa. Some fields possess a large number of plants which mature before the main crop. In many bins of wheat are to be found white and red kernels. These mixtures are often due to mechanical mixing, especially through the use of custom threshing machines.

The presence of white and yellow grains of corn on the same ear is a well-known occurrence. This mixing of varieties is to be avoided, since it may cause a decrease in yield and deviation from the varietal type. Sometimes spring vetch is found mixed with the seed of winter vetch. The latter is very winter hardy, while the former is very susceptible to winter-killing. Therefore, when winter vetch mixed with spring vetch seeds is used the amount of winter-killing is usually increased. It is never a good plan to mix varieties unless the grower is sure of his methods. As a rule a decrease in yield results and the variety characteristics are lost.

CHAPTER VIII

THE VALUE OF GOOD SEED

The use of seeds of good quality is of great importance in crop production. Although this fact is well recognized by the more progressive farmers, far too many seeds of inferior quality are being used. A knowledge of the qualities that make for good seeds is, therefore, very desirable.

Qualities of Good Seeds.—Not only must good seeds belong to a good variety but they must have (1) strong germination, (2) proper size and development, (3) uniformity, (4) freedom from disease and (5) freedom from mixtures.

Germination.—Seeds which will not germinate are, of course, worthless while those which will germinate but produce weak seedlings may be almost worthless. Germination tests may be used to determine the viability of seed. These tests are usually simple and inexpensive and should be resorted to whenever there is any doubt about the viability of seeds which are to be planted.

Size and Development.—The size of seeds is usually largely determined by the amount of reserve food supply carried for the young plant; and it is important that seeds be large, plump and well developed. If the seeds are small or shrunken, they may not contain enough stored food to give the plants a vigorous start. Plants grown from poorly developed seeds may thus be stunted in the early stages of growth and never recover sufficiently to produce normal plants.

Cummings (1914) in Vermont working with peas, Hubbard squash, lettuce, spinach, parsley, radishes and beans obtained a decided advantage in favor of large seeds over small seeds of the same variety. He states: "The weights and sizes of plants compared at different stages of growth show that a continuous and permanent advantage exists in favor of large seed. Plants grown from large seed possess more leaves of greater surface area and hence have greater assimilative powers."

Hicks and Dabney (1896) report results of greenhouse experiments conducted with peas, beans, soybeans, vetch, rye, barley, wheat and oats: "There was, in every instance, a marked increase in the weight of the seedlings from the heavier seed which was closely proportionate to the difference between the weight of the seed." Williams (1916) of Ohio found very little difference in the yields of large and small grains of wheat as separated by the fanning mill, but with hand-selected seeds the average

of a 6-year test showed a 48 per cent increase in favor of heavy seeds over light. He states: "As a result of both of these tests it seems to be apparent that heavy kernels may be expected to give larger yields of wheat than light kernels, if the differences in weight of kernels are large enough; certainly is this true in pure lines, and possibly in a mixed population." Biometric studies with wheat conducted by Love (1910) at Cornell University also indicate a relation between size of seed and yield. He says: "From the data in hand and other data which have been obtained at this station, we are safe in stating that if large (heavy) seed of wheat (also oats) are used for planting, they will come from the tallest, heaviest yielding individuals. Then, if there is a tendency for the parent plant to reproduce its type, a large yield may be expected from the heaviest seed."

A few experimenters have reported a failure to obtain increased yields from the use of larger seeds, but the preponderance of evidence seems to be in favor of large seeds over small seeds.

Uniformity.—If seeds consist partly of fully developed grains and partly of small, weak grains, some strong and some weak plants will probably be produced. The large plants will have a tendency to crowd out the smaller ones, and thus reduce the stand. The plants from the inferior seeds may be more subject to attacks of diseases and insects, and in most cases may mature later than the stronger seeds. In the case of certain large seeds, such as corn and beans, it is important that the seeds be of uniform size so that they may be evenly distributed with planters. For all of these reasons it is desirable that seeds for planting be as uniform in size as possible. Large and small seeds from the same plant frequently carry the same hereditary characteristics and under ideal conditions may give similar results in yield. However, large seeds well stored with food produce more vigorous young plants than small seeds, and under adverse conditions may be expected to produce better plants.

Freedom from Disease.—It is a well-known fact that many of the most serious plant diseases are carried on the seeds. Among these may be mentioned, smuts of small grains root rot in corn, scab in potatoes and "wild fire" or leaf spot in tobacco. These diseases cause enormous annual loss to the farmers of the country and no seed may be truthfully said to be good seed unless it is comparatively disease-free.

Freedom from Mixtures.—Adulterated or mixed seeds are objectionable because they produce a product which usually brings a low price on the market and because they often carry seeds of noxious weeds which may become serious pests. The selling price of a small grain is always reduced if it contains an appreciable amount of any other small grain. In sections where rye and wheat are both grown, rye is often found in seed wheat. Such seed wheat is undesirable, as it will produce a product which is low in milling quality and which will bring a lower price than rye-free wheat.

Mixed grain of other cereals also sells at a reduced price. Some of the most objectionable farm weeds have been introduced in seeds. Wild onion, quack grass, Canada thistle, knawel, wild mustard, wild carrot and corn cockle have been widely disseminated in impure seed. From an economic standpoint, these weeds present a serious problem. Pieters (1900) found that in one sample of seed which contained only one-fifth of one per cent of foreign seeds there were 990 weed seeds per pound. If such seeds were sown at the rate of 10 pounds to the acre, 9,900 weed seeds would be sown to the acre, or approximately enough to place one weed seed on every 5 square feet of the acre. This sample would ordinarily have been classified as good seed, and yet it carried enough weed seeds, if all of them were viable, to seriously reduce the quality of the crop.

Conditions Which Affect Quality.—The conditions which affect the quality of seeds are (1) method of production, (2) method of handling and (3) method of storage.

Method of Production.—In order to produce good seeds, sound, well-developed, disease-free, unadulterated foundation stock should be used. Such stock should be planted on good ground and given good cultivation. If noxious weeds appear they should be removed before the seed crop is harvested. To produce good seed on good ground requires care and discrimination. To produce good seed on poor land with careless methods of culture is very difficult. The benefits to be derived from good seed will more than pay for the extra care and labor necessary to produce them.

Method of Handling.—Seeds for planting should be very carefully handled at harvest time, during the period which intervenes between harvest and final storage, and care should be taken not to harvest the crop until the seeds are mature. Immature seeds will usually lack plumpness and vigor. In the case of small grains, the shocks should be well made and every precaution taken to prevent water from entering the shocks and stacks. After the seeds are threshed, they should be spread in a thin layer and stirred until thoroughly dry. Damp grain will heat in the bin and heating reduces germination.

In the case of corn it is best to harvest the seed separately from the rest of the crop and place in some location where it will dry out quickly. When seed corn is harvested from standing stalks, plants may be avoided which show signs of weakness of any kind. Holbert and Hoffer (1920) found that ears from leaning or broken stalks, drooping ears, ears from broken shanks and ears from prematurely dead stalks are likely to be affected with root rot and that, when planted in experimental plats, such ears give greatly reduced yields. It is best to take for seed purposes only matured ears of medium size from upright plants whose stalks are still green and whose ears are supported, at a convenient height, on strong, sound shanks.

Precautions for handling grass and clover seeds are very similar to those for handling the small grains. The chief consideration is to see that the crop does not heat, either before or after threshing.

Method of Storage.—The chief precaution to be observed in the storage of seeds is to see that the seeds are dry before storage and to keep them dry in storage. Duvel (1904) has shown that seeds deteriorate very rapidly when stored in damp rooms, even if the seeds are thoroughly dry before storage. Seeds, which are subject, while in storage, to the attacks of insects, such as weevils, should be treated before storing to destroy these insects and should be kept in tight bins or receptacles.

Profits from the Use of Good Seeds.—Since the terms "good" and "poor" as used in reference to seeds can be only relative measures of quality, it is impossible to say exactly how much profit can be derived from the use of good seeds. However, the results of experiments with different kinds of seeds give considerable usable information on this subject.

Hays (1893) in Minnesota divided oat seeds into heavy and light groups by use of the fanning mill. The heavy seeds, as separated, weighed 37 pounds per bushel and the light seeds 21 pounds per bushel. These were sown in experimental plats at the rate of 2 bushels to the acre. The heavy seeds yielded at the rate of 64.09 bushels per acre and the light seeds at the rate of 54.59 bushels per acre; a difference of 9.5 bushels to the acre in favor of heavy seeds. The same author obtained 36 per cent increase in the yield of heavy wheat seeds over light wheat seeds.

Nicholson and Lyon (1896) working with sugar beets in Nebraska found that large seeds gave a decided increase in yield over small seeds, as shown by the results given in Table XIV.

TABLE XIV.—THE EFFECT OF SIZE OF SEEDS ON THE YIELD, PERCENTAGE OF SUGAR AND PURITY OF JUICE OF SUGAR BEETS IN NEBRASKA

Kind of seed	Yield on plat, lb.	Sugar in beets, per cent	Purity of juice, per cent
Small	833	11.3	73.8
Medium	845	11.0	72.4
Large	1,100	12.8	78.6

In this experiment the large seeds were retained in a 5-millimeter sieve, the medium seeds passed through a 5-millimeter sieve but were retained by a 3-millimeter sieve, and the small seeds all passed through a 3-millimeter sieve.

Shamel (1905) in Connecticut separated tobacco seeds into light, medium and heavy grades and observed the growth of plants produced from each grade. He states: "In all cases. . . the plants from small seed,

when set in the field, developed a large percentage of undesirable plants which are almost a total loss to the grower." Therefore, it is extremely important that the tobacco growers separate out the light and small seeds before sowing the seed beds. The loss from planting seeds of low vitality is always large as there is a loss of labor in cultivating land on which no plants are present and an additional loss in obtaining reduced yields.

Hume (1904) in Illinois tested a large number of ears of seed corn obtained from seed-corn growers and found that the "good corn" as determined by the test germinated 8.81 per cent more than the composite lot of seed corn. Hughes (1913) found at the Iowa Experiment Station that the testing of the viability of seed corn before planting increased the profits 93.6 per cent in 1910 and 85.7 per cent in 1911. This is the result of 45,000 ear test readings made in the years mentioned.

The experiments with smuts in small grains and root rot diseases in corn serve well as illustrations of the losses due to planting diseased seeds. Boss and others (1909) in Minnesota report that the grain smuts cause an annual loss in the crops of Minnesota that may be conservatively placed at 10 per cent; and they state that the yield of oats is often reduced 20 to 25 per cent by smuts. By planting disease-free seed ears, as determined by the modified rag doll germination test, Hoffer (1920) found in Indiana that the yield of sweet corn was increased 1 to 25 per cent, the amount of increase depending upon the kind of weather occurring during the growing season. Holbert (1920) estimates that the root rots are decreasing the yield of corn in Illinois fully 15 per cent, and that the diseases are increasing throughout the corn belt. Many other illustrations could be cited to show the extent of losses due to planting poor seed, but these are sufficient to show that cheap and inferior seeds are poor economy.

Returns Based on the Unit of Investment.—Conservative agronomists estimate the yields from the use of pure, well-developed, disease-free seeds to be from 10 to 20 per cent greater than those from ordinary market seeds. Seeds of the best quality obtainable seldom sell for more than twice the price of ordinary seeds. Assuming that the quantity of corn of the best quality for seeding an acre costs $1 and that ordinary seed for an acre costs only 50 cents, the increased cost of seeding will be 50 cents an acre. If the ordinary seeds produce 25 bushels to the acre and the good seeds increase the yield only 10 per cent, 2.5 bushels of corn will have been obtained for the investment of 50 cents. The increased yield of corn would, in such a case, cost only 20 cents a bushel up to harvest time. Similar results could be shown for other kinds of seeds.

Money invested in good seeds is good insurance. Good seeds may be produced on the farm with a little extra care and expense or may be bought from certified seed associations. Since this is the case, it is false economy to introduce an additional hazard into farming by the use of seeds of doubtful value.

CHAPTER IX

HOW TO SECURE GOOD SEEDS

Even when it is realized that good seeds are important and necessary to obtain large yields, it is not always easy to secure them. At the present time not enough seeds of high quality are produced to plant the acreage annually planted to crops; in fact, the actual demand is greater than the supply. Therefore, a knowledge of practical means of securing a larger supply of better seeds is worth while.

Methods of Securing Good Seeds.—Good seeds may be obtained by (1) selection and breeding on the farm and by (2) purchase from reliable breeders and dealers.

Improvement of Seeds on the Farm.—The question of plant improvement under farm conditions has been discussed in Chapter VI. It is doubtful whether any farmer can afford to neglect the improvement of home-grown seeds. It has been shown that variations take place in all directions and that there are retrogressive as well as progressive variations. If no attempt is made to select the best seeds for planting and if no care is taken to eliminate diseases and mixtures, the yields of most varieties soon become lower. The practice of buying seeds which can be produced at home is usually wasteful as it involves transportation charges and cost of containers as well as a profit for each dealer who handles the seeds. Then, too, if one is not sure of the locality in which the seeds were grown, non-acclimated seeds may be obtained. Carrier (1913) in Virginia has shown that home-grown seed corn of the same variety gives larger yields than seed from other counties in Virginia as well as larger yields than seed from other states. There are many similar experiments which prove rather conclusively that home-grown seeds are usually better.

Purchasing Seeds.—Up to comparatively recent years it was practically impossible to buy seeds of guaranteed quality. In fact, at the present time a large number of seed houses specifically state on the container in which the seeds are shipped that they do not guarantee the seeds sold. The following is a typical statement which accompanies each shipment of seeds from certain seed houses: "We give no warranty, expressed or implied, as to description, quality, productiveness or any other matter of any seeds, bulbs, or plants we send out, and will not be in any way responsible for the crop." Such statements, instead of implying a desire on the part of the seedsmen to evade responsibility, in many cases are

necessary for their protection. Large seed houses cannot grow all of the seeds they sell; and since they cannot buy under a guarantee, they cannot afford to sell under a guarantee. In recent years, however, a few private companies have been organized for the purpose of producing and selling guaranteed seeds, and many sections have crop improvement or seed associations made up of farmers who grow and sell seeds guaranteed under a rigid system of inspection. When seeds are to be purchased, it is usually best to buy from a company that gives a guarantee even if a much higher price has to be paid.

Storage of Seeds.—As discussed in Chapter VIII, the most important considerations in the storage of seeds are to see that they are dry when placed in storage and to keep them dry during the storage period.

Kiesselbach and Ratcliff (1918) in Nebraska found that seed corn which contained 25 per cent or more of water was greatly injured by freezing weather, while corn which contained 10 to 14 per cent moisture was not injured by any amount of freezing within the limits of the experiment. Hartley (1911) found that the germination of apparently dry corn was greatly reduced when the corn was left in sacks or piles for even a day after gathering. It is, therefore, desirable that seed corn be thoroughly dried as soon after gathering as possible. Artificial heat is sometimes used to dry out seed corn, but in most cases corn can be air-dried thoroughly enough to insure germination, if placed where air can circulate freely around it. Many types of racks and frames have been devised for curing seed corn. However, almost any type of storage which insures free circulation of air and keeps the seed out of the reach of rats and mice will give good results.

In sections of the country where weevils and other insects are prevalent, these insects must be destroyed by fumigation while the seeds are in storage. In certain parts of the South weevils are very destructive to corn, wheat, beans and peas, and when seeds of these crops are stored in that section they should be placed in tight containers and treated with carbon bisulphide. One pint of carbon bisulphide is recommended for each 20 bushels of seed. The seeds are placed in a tight bin or container and the carbon bisulphide is poured into a shallow receptacle on top of the seeds. The bin is then tightly closed. The volatile fumes of the carbon bisulphide, being heavier than air, penetrate the seed mass and kill the insects.

Seed Testing.—Examples have already been given to illustrate the advantages of germination tests. If seeds are carefully cured and stored, they usually germinate well. However, a germination test is the only positive way of determining whether or not seeds may be expected to germinate. Such tests are always advisable before planting, but they are of particular importance when the method used in curing and storing the seeds is unknown. Germination tests not only show the total percentage

of viable seed but show whether the germination is strong or weak and in some cases indicate the presence or absence of certain seeds which are the carriers of diseases. The modified rag doll germinator as described by Holbert and Hoffer (1920) offers a simple method of detecting root rot diseases in germinating corn.

Many types of germinators are used in testing seeds but the principle underlying all of them is simply to keep the seeds under proper temperature and moisture conditions for germination. Except in the case of corn, where the individual ear germination test is advised, a random composite sample is usually taken and a given number of seeds are placed in the germinator. Proper moisture and temperature conditions are maintained until the seeds have been given sufficient time to germinate. The seeds are then removed from the germinator and the amount of germination determined.

Testing for Purity.—Weed seeds may be easily detected in large seeds, such as corn, peas, beans and the small grains. However, in the case of small seeds, such as the clovers and grasses, a purity test is often of considerable importance. DeLoach and others (1909) collected grass and clover seeds from various commercial sources in Virginia and examined them for purity. In some cases these seeds were found to contain as high as 20 per cent of foreign seeds, many of which were noxious weeds, such as dodder, curled dock, plantain, sorrel and foxtail. Many weed seeds are small and similar in appearance to useful seeds and can be detected only by careful examination. Since weeds present such a serious economic problem on farms, every precaution should be taken to sow grass and clover seeds which are comparatively weed-free.

Seed Associations.—For many years seeds have been produced and sold by organized groups of farmers. The object of the early seed associations was to grow and market seeds of a somewhat better quality than ordinary commercial kinds without any reference to the pedigree of the plants producing the seeds.

The modern seed associations have as their object the production of seeds of known ancestry which can be guaranteed to be pure, viable and reasonably free from seed-borne diseases. Pedigree breeding has been practiced by breeders of animals for many generations. The modern seed associations attempt to apply to plants, in so far as it is practicable, the methods of registration and certification which have been used by animal breeders. The term "registered seed" as used by plant growers has practically the same meaning to them as the term "registered" has to producers of live stock. The chief difference is that practically any animal which is the progeny of registered ancestry may be registered, while certified seeds must be the progeny of registered ancestry and must also comply with a certain standard of perfection. The associations for producing such seeds are usually made up of farmers who cooperate with

the agricultural experiment stations and use methods advocated by them. Owing to the fact that there is such a great variation in the adaptability of crops, it is not practicable to have large national associations handle the registration of seeds as is done in the case of animals. However, there is a national crop improvement association made up of representatives of the state seed associations. The duty of this association is to standardize the requirements for seed registration in the various states.

The Canadian Seed Growers' Association was the pioneer seed association of the modern type in the new world and the Minnesota Field Crop Breeders' Association was one of the earliest of such associations in the United States. Other states which have well-developed seed associations are Michigan, Ohio, Wisconsin, Missouri, Kansas, North Dakota, Massachusetts, Washington, Pennsylvania, Virginia and Oklahoma. The seed association idea represents a distinct step in the advancement of agriculture and will doubtless spread rapidly to many other states in the Union.

Advantages of Seed Associations.—While any grower may apply to his own farming operations the methods used by seed associations without regard to the association, yet affiliation with such associations brings certain advantages which are a great asset to growers. These, according to an undated report of the Canadian Seed Growers' Association are:

1. It enables the grower to keep in touch with his fellow worker and thus to profit by the successes and failures of the latter.
2. It keeps him in touch with the best thought of the times in all matters pertaining to crop raising.
3. It fixes approximate standards of registration for pure-bred seed.
4. It makes a careful study of the results obtained by the different members as well as by professional investigators, and offers direction and guidance accordingly.
5. It keeps the records of all work done along these lines by members and issues certificates of registration.
6. It assists members as far as possible in the disposal of their surplus stock of pure-bred seed at a reasonable rate.
7. It gives publicity to the work of worthy growers who have succeeded in producing stock of real merit.

Production of Registered Seeds.—The usual requirements for the production of registered seeds are (1) that the seeds be grown from certified seed stocks; (2) that the crops pass an inspection for mixtures, weeds and diseases in the field; and (3) that the harvested crops attain the standard of perfection set by the association. Registered seed stocks may be obtained from members of the association who are already producing registered seeds and from experiment stations, or they

may be produced by compliance with certain regulations and requirements of the association.

The field inspection is made by an agent of the association who has had sufficient training in agronomy, plant pathology and botany to enable him to determine if the seeds as grown in the field are true to type, and are free from noxious weeds and seed-borne diseases. After the seeds have been threshed, representative samples are taken and carefully analyzed. Determinations are made of weight per bushel, foreign material, germination, moisture content, purity and percentage of large, whole seeds. The field and final inspections taken together furnish complete and reliable information as to the quality, condition and purity of the seeds. If the seeds meet the established standards in both inspections, they are certified and admitted to registration, and may then be sold as certified seeds or used as foundation stock for the production of certified seeds. The registered seed associations keep complete records showing by whom and in what year the seeds were produced. These records also show the locality in which the crop was grown, and give a complete analysis of the seeds based on the field and bin inspections. A certificate of registration bearing all necessary information, including the registration number of the particular lot of seeds, is given to the grower. All seeds sold as certified or registered seeds bear the association's stamp of approval and are shipped under a tag which carries the grower's name and a guarantee of purity and germination.

Seeds grown and sold under such regulations are far superior to ordinary commercial seeds. It is estimated that the use of registered seeds in Michigan has increased crop yields not less than 10 per cent. Since it costs more to produce registered seeds than it does to produce ordinary seeds, the registered seeds sell for more than unregistered stock. However, the extra cost of the seeds is more than compensated for in larger yields of better quality.

Seed Laws.—Many of the states of the Union have seed laws designed to control the quality of the seeds sold within their borders. It is evident that the purpose of such laws is to raise the standard of seeds and to protect the citizens against the possibility of buying seeds of inferior quality. There is a considerable variation in these laws in the various states. In most states the laws do not forbid the sale of seeds of low quality but merely require that a statement of the germination and purity of the seeds accompany each package of seeds sold. In some cases the seed dealer is required to state on the shipping tag the kind and percentage of foreign seeds in the seeds sold, in other cases no seeds can be sold which contain more than a stated quantity of certain noxious weed seeds. These laws have done much to improve the quality of commercial seeds. However, when farmers buy seeds by mail order, they usually get no information concerning the quality of the seeds purchased until they

read the accompanying statement of quality after the seeds have been received. Seed laws could be greatly strengthened if dealers were required to furnish, with their price lists, statements of germination and quality.

The seed laws are frequently enforced by state departments organized for this purpose. These departments keep inspectors in the field who are authorized to draw samples of seeds wherever found. The samples are then analyzed; and if they are being sold contrary to law, the dealer is subjected to the penalties of the law.

Most of the seed laws do not cover garden or field seeds sold in small packets. If such laws were extended to cover all seeds sold regardless of quantity, their usefulness would be greatly increased.

CHAPTER X

PREPARATION OF THE SEEDBED

The preparation of a good seedbed is one of the most important factors in profitable and economic crop production. No other factor will entirely take the place of a well-prepared seedbed, not even good seed, proper fertilization, judicious cultivation and optimum moisture supply.

Right Preparation Increases Yield.—The chief reason for preparing the seedbed well is to secure increased crop yields. Good crops usually cannot be produced on poorly prepared ground. There are numerous results of experiments which bear out this statement.

Fig. 6.—Seeding wheat on a well-prepared seedbed. (*U. S. Dept. Agr., States Relation Service*).

Where wheat is to be planted the land should usually be plowed early. The results reported by Sewell (1919) from Kansas show that a dark brown silt loam planted continuously in wheat gave much better yields when plowed early and comparatively deep. In this experiment the land was plowed 3 to 7 inches deep and at different dates, from July 15 to September 15. The 7-inch plowing on July 15 gave the best results. Other results from the Kansas Experiment Station indicate that plowing deeper than 7 inches for wheat is not advisable.

Table XV.—Average Yields of Wheat Obtained from Methods of Seedbed Preparation on Land Cropped Continuously to Wheat at the Kansas Experiment Station (Average 8 Years, 1911 to 1918)

Treatment	Average yield in bu. per acre
Disked at seeding time	6.8
Plowed Sept. 15, 3 in. deep	12.7
Disked July 15, plowed Sept. 15, 7 in. deep	17.5
Disked July 15, plowed Aug. 15, 7 in. deep	18.2
Listed July 15, ridges worked down	17.5
Listed July 15, ridges split Aug. 15	17.4
Plowed July 15, 7 in. deep	20.8
Plowed Aug. 15, 7 in. deep, worked immediately	19.5
Plowed Aug. 15, 7 in. deep, not worked until Sept. 15	18.1
Plowed Sept. 15, 7 in. deep	13.5
Plowed July 15, 3 in. deep	16.4

At the Ohio Experiment Station, Williams and Welton (1915) compared the results obtained from corn, oats, wheat and clover in rotation on land plowed in the ordinary way, on land plowed deep and on land subsoiled. The results as presented in Table XVI show that deep plowing and subsoiling have not increased the yields of these crops. The deeper plowings are more expensive, and under the conditions of these experiments ordinary plowing is to be recommended.

Table XVI.—Average Yields per Acre of Various Crops under Various Tillage Treatments at the Ohio Experiment Station (Average 5 Seasons)

Crop	Treatment		
	Plowed 7.5 in. (ordinary)	Plowed 15 in. (deep)	Subsoiled
Corn, bu	60.69	61.12	63.01
Oats, bu	45.49	43.80	45.11
Wheat, bu	32.73	33.90	34.19
Clover, tons	2.43	2.35	2.34

Noll (1913) at the Pennsylvania Experiment Station compared results obtained from ordinary plowing, 7.5 inches, with those obtained from the use of the Spaulding deep-tilling machine, the soil, which was mostly a clay loam, being plowed to a depth of 12 inches. The trial covered a

period of three years in which corn, oats, barley, wheat and alfalfa were grown. The two kinds of plowing gave practically the same results.

Sanborn (1893*a*) in Utah, found that land planted to barley, oats and wheat should be well prepared, but not excessively worked. Unplowed land gave the poorest results, the average yield per acre for the three crops being 12.2 bushels. The yield from ordinary harrowing of plowed land was 15.78 bushels, from disking 21.11 bushels, from excessive harrowing 14.46 bushels. The soil used was a sandy loam.

Mosier and Gustafson (1915) in Illinois found that the yield of corn on brown silt loam soil not plowed or cultivated but hoed free from weeds, was 31.4 bushels per acre based on an 8-year averge. The yield from land plowed and treated similarly to the above was 45.9 bushels, a difference of 14.5 bushels in favor of the plowed seedbed.

Morrow and Gardner (1892), at the Illinois Experiment Station, found that in a loose open soil the proper depth to plow land for corn was from 4 to 8 inches. The results of their experiment are shown in Table XVII.

Table XVII.—Yield of Corn from Seedbed Plowed to Various Depths

Treatment, 1890	Yield in bu. per acre	Treatment, 1891	Yield in bu. per acre
Not plowed, disked shallow	56.4	Plowed 2 in. deep	54.0
Plowed 2 in. deep	59.9	Plowed 5 in. deep	57.5
Plowed 4 in. deep	69.4	Plowed 10 in. deep	56.0
Plowed 6 in. deep	69.3		
Plowed 8 in. deep	71.7		

Cardon (1915) found in Utah that the 5-year average yield of wheat on cultivated fallow, was 17 bushels per acre. The yield from uncultivated fallow was 13 bushels, a difference of 4 bushels in favor of cultivated seedbed. The soil used was a clay loam. Shaw (1911) in California, found the 2-year average yield of wheat from plowed land to be 3.1 bushels more than that from land unplowed but disked.

The experiments cited show that good preparation of the seedbed is profitable. The results also show that no definite statement can be made as to the amount and nature of the preparation that will be most advisable. The existing conditions necessarily modify to some extent the advice to be given in regard to the preparation of the land for planting.

Implements Used in Preparation of the Seedbed.—The three main classes of implements used in preparing the seedbed are plows, harrows and compacters.

Plows.—There are several types of plows but the most common one is the ordinary moldboard plow. Moldboard plows are divided into stubble, general-purpose and sod plows, according to the kind of moldboard. The stubble plow, with its short, strongly curved moldboard pulverizes the soil to a great degree. This type of plow is good to use in old cultivated lands. But little pulverization is obtained by means of the sod plow, which has a long, slightly curving moldboard. The general-purpose plow has a moldboard intermediate in length and curvature between the stubble and sod plows.

Some of the other types of plows are the disk, lister, subsoil, and hillside plows. The disk plow is especially good for plowing hard, dry land. The lister is a plow with a double moldboard used in semi-arid regions for opening furrows in the bottom of which the seed is to be planted. The subsoil plow is employed to loosen the soil in the bottom of the furrow made by the ordinary plow. The hillside or swivel plow is a form of moldboard plow made in such a way that the moldboard may be reversed. This type of plow is used for plowing on comparatively steep hillsides.

Harrows.—Of the harrows used in preparation of the seedbed may be mentioned the spike tooth, spring tooth, acme or blade and disk.

The spike tooth harrow usually consists of two to four sections the teeth being set at various angles by means of levers. It is very effective in pulverizing and to some degree in compacting land that has been freshly plowed. The "A" harrow is used by some farmers instead of the spike tooth. The spring tooth harrow is more efficient in loosening soil than the spike tooth harrow, and is used mostly on soils low in organic matter and poor in physical condition. The acme or blade harrow serves a very useful purpose in pulverizing and compacting the soil. The disk harrow is of several types: the solid disk, the cut-away disk and the spading disk. The disk harrow ranks next in importance to the plow in the preparation of land for seeding. It is very effective in stirring, pulverizing and compacting the soil.

Compacters.—There are various forms of implements used to compact the soil. Among these are the smooth or drum roller, the culti-packer or corrugated roller, the bar roller, plankers and subsurface packers.

Compacters are used to crush clods on heavier soils, to firm the soil in case of the lighter kinds of soils, such as sands and sandy loams, and to smooth the surface of the soil. The subsurface compacters are used in arid and semi-arid regions to firm the soil beneath the surface. In this way moisture is better distributed and conserved.

The smooth roller is used extensively, but is being very largely replaced by the culti-packer, as the latter crushes the clods to a greater degree. The culti-packer is also effective in firming the soil and leaves the surface of the ground covered with a thin mulch instead of smooth,

as does the smooth roller. The bar roller is said to be intermediate in effectiveness between the smooth roller and the culti-packer. Plankers are excellent for crushing clods and leveling the ground, but they are not very efficient in compacting the soil.

Plowing.—Plowing is an art and the ability to plow land well comes only by practice. Plowing is usually the first step in the preparation of the seedbed. In this operation the soil is loosened, the vegetable material on the surface is turned under and there is a more or less complete inversion of the soil, which brings about pulverization. If these objects are to be satisfactorily accomplished, the soil should not be too dry or too wet when the plowing is done. If soil is too dry when plowed, it is likely to break cloddy and the amount of pulverization will be reduced. A soil plowed when too wet is likely to be greatly injured on account of the puddling or breaking down of the soil granules.

Plowing is one of the most important steps in seedbed preparation and if properly done, much labor is saved later on. In well-plowed land the entire furrow is cut and turned; the plowing is usually from 5 to 7 inches deep, or sufficiently deep to allow thorough pulverization of the soil; the organic material turned under is well covered with soil; and usually the furrows are straight.

Depth of Plowing.—It seems that extremely deep plowing is not necessary for the ordinary field crops. Deep plowing does not necessarily decrease the yield but the increase, if any, is often slight and not sufficient to pay the extra expense incurred in the operation. Under ordinary conditions with the common field crops, a desirable and practicable depth to plow seems to be about 5 to 8 inches. However, the depth to which land should be plowed will frequently vary somewhat with the time of plowing and kind of soil. In the late fall and winter, when the land is to be planted in the spring, the plowing may frequently be deeper than when land is to be planted soon after plowing.

Especially is this true in case of heavy soils, such as clays and clay loams, when some of the subsoil is brought to the surface, as the freezing and thawing will aid in the disintegration of the exposed subsoil.

Sewell (1919) gives the results as shown in Table XVIII obtained by Latta with corn in a depth-of-plowing test in Indiana.

TABLE XVIII.—AVERAGE YIELDS OF CORN PRODUCED AT THE INDIANA STATION ON LAND PLOWED TO VARIOUS DEPTHS IN THE 4 YEARS FROM 1891 TO 1894

Depth of plowing, in. . . .	4	6	8	10	12	14	16
Yield in bu. per acre. . . .	33.77	34.19	35.14	34.49	35.00	34.84	34.14

The results show but slight differences in yield from the different depths of plowing. However, there is a slight increase until the 8-inch depth is reached.

Time of Plowing.—The time when plowing should be done will vary with the climate, crop and soil conditions. In the drier sections of the country the land should be plowed and kept prepared for as long a time as possible before the crop is planted. In the humid sections the time of plowing will depend on the crop and conditions of the soil. In the case of such crops as wheat, rye, oats and barley, when fall-sown, the plowing should be done in the summer. The plowing of land for corn, cotton, oats, barley, cowpeas, soybeans and other spring-sown crops may be done in the fall or the spring. Sod lands and heavy soils, such as clays and clay loams, which are to be planted in the spring should be plowed in the fall or winter and the seedbed further prepared in the spring.

Examples.—The importance of the time of plowing may be shown by the results of several experiments.

Call (1913) in Kansas found that when land was plowed 7 inches deep on July 15, the yield was 27.11 bushels of wheat per acre as a 3-year average; when plowed 7 inches deep on August 15, the yield was 22.19 bushels; and when plowed 7 inches deep on September 15, the yield was 14.15 bushels.

In western Kansas, where the annual rainfall is less than 25 inches, Call (1913) found that fallowing and early plowing increased the yield of wheat under such conditions because of greater conservation of moisture. Plowing in the early fall compared with late fall increased the yield of wheat 5.2 bushels per acre. Fallowed land produced 15.3 bushels more to the acre than land plowed in late fall. The experiment extended over a 4-year period.

In Kansas, Georgeson and others (1897) found that land plowed in the fall produced 55.36 bushels of corn per acre, while land plowed in the spring produced 54.67 bushels, which is only a slight difference in favor of fall plowing.

Lyon (1898) found in Nebraska that loam soil plowed in the fall, (September) yielded 75 bushels of corn per acre, while that plowed the following April yielded only 56 bushels. A difference of 19 bushels per acre in favor of fall plowing argues well for plowing at this season.

Fall Plowing.—There are certain conditions that make late fall and winter plowing expecially desirable. At this time there is no special rush of other work; organic matter can be turned under and given time to decay; the soil has a chance to settle; the freezing and thawing characteristic of this season improve the structure of the soil; plant nutrients become more available; many perennial plant roots, insects and their eggs, are destroyed by being disturbed and exposed to the cold; and in the fall the land may be plowed without injury when it is much wetter or drier than in the spring.

Fall plowing may start any time after the weather becomes cold. It is not a good plan to plow land in the fall while nitrification is likely to

be active. Plowing the soil makes conditions especially favorable for this process; and as no crop is growing on the land, much of the nitrates may be lost. There is but little nitrification taking place in the late fall and winter and but small amounts of nitrates will be formed before spring.

It is not always desirable or advisable to plow land in the fall. Usually soils very poor in organic matter should not be plowed at this season, as such soils tend to run together instead of becoming granular. Also, in regions of high winds the loose, open soils, poor in organic matter, are likely to blow badly. Where practicable, it is better to plant such lands in cover crops in the fall and plow them in the spring.

Land plowed in the fall or winter should be left rough until spring when it should be harrowed and put in condition for planting. Land left rough during the winter catches and holds more of the snowfall and retains the rainfall more effectively.

Spring Plowing.—Much plowing must necessarily be done in the spring. When land is plowed at this time, more work is required to get it into condition for planting than in the case of land plowed in the fall. It has not had the chance to settle, the organic matter has not had opportunity to decay and the soil is not so well granulated as soil that has been plowed and exposed to the freezing and thawing of the winter. Thus, in the case of spring-plowed land many of the desirable characteristics of the seedbed can be secured only through tillage, while with fall-plowed land some of these characteristics are developed through natural processes.

Deep Tilling, Subsoiling and Dynamiting.—The results of some experiments show that the practice of deep tilling, subsoiling and dynamiting is profitable. However, most of the experimental results do not show this to be the case. It seems probable that the practices of deep tilling, subsoiling and dynamiting are not advisable for the ordinary crops grown under the conditions that generally prevail.

Benefits of Good Preparation.—The beneficial effects secured through preparation of the land for seeding are the following: (1) conservation of moisture; (2) destruction of weeds; (3) better aëration of the soil; (4) turning under the organic material; (5) pulverizing and loosening the soil; and (6) compacting the soil.

Conservation of Moisture.—Widtsoe (1908) in Utah found that summer fallowing conserves the soil moisture, and the longer the fallowing period the greater the moisture conserved. Merill (1910) in Utah found the average percentage of water in the top 6 feet of a fallowed sandy loam soil to be 16.58, while that in the plat cropped for 7 years was 11.48, a difference of 5.1 per cent in favor of fallowing. Burr (1914) in Nebraska found that summer tilling a fine sandy loam loess soil conserved 33 per cent of the rainfall in one instance and 24 per cent in

another. The value of mulches in preventing the loss of water under Nebraska conditions is shown in Table XIX.

TABLE XIX.—EFFECT OF MULCHING ON SOIL MOISTURE, 1912. PERCENTAGE OF MOISTURE IN THE SOIL, AVERAGE OF THE TOP 6 FEET

Kind of mulch	Aug. 28	Sept. 5	Nov. 15
Hay	18.8	16.4	17.0
None	18.3	15.0	11.7
Soil	18.0	16.2	14.3

The unmulched soil lost 6.6 per cent moisture, the soil mulched with hay lost 1.8 per cent and the soil-mulched plat lost 3.7 per cent.

The conservation of moisture is especially important in the dry-land sections of the country. In such sections the rainfall of one season is often insufficient to produce the crop. However, if the land is kept in fallow one year, a crop can be grown the following year. As a result of fallowing, much of the rainfall is stored in the soil and this moisture, with the rains of the growing season, may be sufficient for producing the crop. Not only is the preparation of the seedbed important from a moisture conservation standpoint where dry farming is followed, but in humid sections the same principle applies. In the latter sections rainfall is often scant during parts of the growing season and the plants draw heavily upon the water previously stored in the soil.

Killing Weeds.—Weeds use large quantities of water and plant nutrients, and in many instances the killing of weeds may be the chief factor in moisture conservation. The loss of moisture and plant nutrients by the growth of weeds is discussed in Chapter XV.

Aëration of the Soil.—In a well-prepared seedbed conditions are favorable for the plant nutrients to become available to plants. This fact may be due largely to the thorough aëration of the soil, since air is necessary for some of the chemical and biological activities in the soil. In the preparation of the seedbed, the soil is exposed to the air and as a result the inert plant nutrients become more available through such processes as oxidation and carbonation, oxygen also being furnished for the formation of nitrates. Thus, through tillage the soil air is modified and diffused and as a result more nitrates are formed and more plant nutrients liberated.

Turning under Organic Matter.—The value of the addition of organic matter is shown by Shaw (1911), quoting from Professor Cavanaugh of Cornell University.

The effect of deep plowing and incorporating organic matter with the soil on the yield of wheat is reported by Shaw (1911). The 2-year

TABLE XX.—THE EFFECT OF CLOVER ON THE MOISTURE, HUMUS AND NITROGEN CONTENT OF THE SOIL AT CORNELL UNIVERSITY

	With no clover, per cent	After clover, per cent	Difference, per cent
Moisture	8.75	15.00	6.25
Humus	1.91	2.94	1.03
Nitrogen	0.12	0.21	0.09

average yield of wheat in the San Joaquin Valley, California, after bare fallow, was 33.3 bushels per acre; after horsebeans, turned under, 37.6 bushels; after field peas, turned under, 36.5 bushels; after wheat, 15.7 bushels; after rye and vetch, turned under, 54 bushels; and after rye, turned under, 52.3 bushels. The soil was sandy, very poor in organic matter and the effect of the green manuring materials in increasing yield was very marked.

The incorporation of organic matter in the soil is necessary for continual high yields of crops. In a well-worked seedbed the organic materials which may have been grown on, or added to the soil, or both, are completely turned under. Such materials add organic matter; a certain amount of plant nutrients; increase the number of organisms in the soil and supply nutrition for them; usually increase the water-holding capacity of the soil; and improve its structure.

Pulverizing and Loosening the Soil.—Soils, especially if clayey, tend to become too compact for crops to grow well. This condition is true notwithstanding the fact that soil organisms and the action of the roots of plants tend to keep the soil loose and open. If large yields of crops are to be obtained therefore, it is necessary to prepare the ground in such a way as to pulverize and loosen the soil. In the preparation of the seedbed the land is stirred, pulverized, loosened and inverted, usually by plowing, disking, rolling and harrowing—the object of the processes being to secure a desirable structure. If the land is properly worked, a crumb condition of the soil particles is developed, in which condition the soil contains a higher percentage of its plant nutrients and moisture in an available state, allows ready access and movement of air, permits easy penetration of roots and is most favorable for the activities of the various soil organisms.

After the land has first been plowed, if best results are to be obtained, it is necessary with practically all crops, to have a firm, compact seedbed properly mulched on the surface. A thorough firming of the soil allows free movement of water by capillary action, brings the furrow slice and subsoil in intimate contact, produces a desirable structure and aids in the control of soil temperature and air.

Some Characteristics of a Good Seedbed.—It is not feasible to attempt to give a discussion of the preparation of the seedbed for the various crops. However, there are certain conditions that hold for all crops. The seedbed is the place where the seeds germinate and the medium from which the resulting plants, through their roots, secure moisture and mineral nutrients. It is desirable, therefore, that the seedbed be in such a condition as to furnish an abundance of moisture, nutrients and air, and to allow full penetration of the plant roots.

FIG. 7.—The culti-packer is very useful in preparing the seedbed.

The best time to prepare the seedbed is before the crop is planted. Too many farmers prepare the seedbed improperly, especially for inter-tilled crops, with the expectation of overcoming by the cultivation of the crop the deficiency in seedbed preparation. A well-prepared seedbed is firm and compact beneath, loose and open on the surface and free from clods. Land in this condition warms readily, and holds a large percentage of its water and plant nutrients in an available form. Moreover, the water and air movements are free and, other things being equal, the plants grow well and make good yields.

It is clear that the seedbed should be well prepared before the seed is planted. In many cases a good indication of a well-prepared seedbed is the absence of clods. Land that has been plowed at the proper time and thoroughly tilled is practically free from clods. Crops do not grow well on cloddy land, as the clods retain quantities of plant nutrients, moisture and bacteria which would otherwise be of benefit to the crops.

Examples.—Rolling is often beneficial in the preparation of the seedbed, as has been shown by King (1890). It was found, under Wisconsin conditions, that rolling of the land increased the germination of oats 4.2, 41.3 and 11.35 per cent; of peas, 35.7 per cent; of barley, 10.3 per cent; and of clover 1.2 and 68.7 per cent, as compared with the germination on unrolled land. The yield of oats on rolled land was 61.12 bushels

per acre with a weight per bushel of 28.25 pounds; the yield of oats on the unrolled land was 58.89 bushels with a weight per bushel of 26.32 pounds.

Morrow and Gardner (1892*b*) report from Illinois that the 4-year average yield of oats grown on a compact seedbed was 46.2 bushels per acre; on a medium seedbed, 48.1 bushels; and on a loose seedbed, 43.6 bushels. This experiment, which was conducted on a productive dark-colored prairie soil, indicates that for oats a firm seedbed is desirable.

It is common practice in certain sections to disk wheat stubble that is to be turned under for a second crop of wheat. Disking aids in the retention of moisture and prolongs the plowing season. The results secured on a fine sandy loam loess soil by Burr (1914) in Nebraska bear out this statement.

TABLE XXI.—EFFECT OF DISKING AFTER THE BINDER ON SOIL MOISTURE IN NEBRASKA (AVERAGE PERCENTAGE OF MOISTURE IN THE TOP 3 FEET OF SOIL)

Treatment	1907		1908				
	July 11, per cent	Aug. 24, per cent	Apr. 23, per cent	May 11, per cent	June 13, per cent	July 2, per cent	July 10, per cent
Soil disked..............	8.4	8.0	10.0	12.8	15.3	16.1	15.0
Soil not disked..........	8.0	5.9	10.2	12.3	14.3	15.4	13.3

Sanborn (1893*a*) in Utah found that unplowed land gave the lowest yield of wheat, while there was but little difference in yield between 4-, 6-, 8-, and 10-inch depths of plowing.

Lyon (1898) reports from Nebraska that fine sandy land disked 4 inches deep yielded 21 bushels corn per acre less than land plowed 8 inches deep.

CHAPTER XI

COMMERCIAL FERTILIZERS

The ten chemical elements essential for the growth of most plants are carbon, oxygen, hydrogen, nitrogen, phosphorus, potassium, calcium, magnesium, iron and sulphur. The plant must secure all of these from the air, the water and the soil. The elements coming from air and water are usually supplied by nature in abundance. Some of those which come from the soil often exist in too small quantities for the economic production of crops and must be supplied. Nitrogen, phosphorus and potassium are the elements in which soils are most often low in amount. These elements are sold in various materials for plant nutrition, and when sold for this purpose either separately or in combination they constitute the so-called commercial fertilizers.

Extent of the Fertilizer Industry.—Statistics from the Fourteenth Census of the United States show that the sale of fertilizers in the United States in 1919 amounted to $326,399,800, which was an increase of 184.1 per cent over 1909. This enormous industry has been built up since 1850 when Sir John Lawes first began the manufacture of bone superphosphate. It will doubtless increase in volume as the population of our country increases. Many of the soils of the West which have hitherto needed no fertilizing are beginning to show the effect of constant cropping and will have to be supplied with plant nutrients if their crop yields are to be maintained. Of the fertilizers sold in the United States in 1919, approximately 57 per cent was sold in the South Atlantic states; one-half of the remainder in the Middle Atlantic and East North Central states and only about 6 per cent was purchased west of the Mississippi River. The greater part of the fertilizers used east of the Mississippi was used on the Coastal Plain soils. These soils, on account of the method of formation, were originally low in available plant nutrients and they have been cropped longer than any of the other soils of the country. However, the use of fertilizers is rapidly increasing throughout the other sections of the country.

Economy in the Use of Fertilizers.—It is an undisputed fact that commercial fertilizers are profitable when properly used, and in many sections are indispensable for economical crop production.

A few examples taken from experiments conducted in Virginia, by Hutcheson and Wolfe (1919), serve well to illustrate this point.

At the branch experiment station located at Chatham, Virginia, experiments were conducted for five years to determine the relative value of heavy and light applications of a standard bright tobacco fertilizer. The results of this experiment are shown in Table XXII.

TABLE XXII.—HEAVY *vs.* LIGHT APPLICATION OF FERTILIZER ON BRIGHT TOBACCO (1913–1917)

Fertilizer used per acre	Yield per acre, lb.	Proceeds
1,400 lb. 3–8–3 fertilizer	934	$135.58
800 lb. 3–8–3	670	94.27
No fertilizer	190	12.59

Westbrook and Hungerford (1922) give the cost of producing bright tobacco in Georgia as $107.13 per acre when the cost of fertilizer is not considered. These cost accounts were obtained in 1920 when prices were very high and are probably somewhat larger than the cost would be in normal years. However, they serve well to show that there is usually no profit in bright tobacco where fertilizers are not used. The best quality of bright tobacco is produced on thin soils which are low in plant nutrients and organic matter. If these lands are improved by the usual methods of soil improvement, such as by the use of lime, legumes and livestock, they become unsuited to the production of bright tobacco; consequently, the farmer must depend upon commercial fertilizers. Hence, it may be said that the economical production of bright tobacco is absolutely dependent upon the use of commercial fertilizers.

Acid phosphate is a fertilizer widely used in this connection for the grain and grass crops in Virginia, and is very effective, as shown in Table XXIII.

TABLE XXIII.—EFFECTS OF AN ANNUAL APPLICATION OF 219 POUNDS OF ACID PHOSPHATE TO THE ACRE ON CORN, WHEAT AND HAY (AVERAGE 1909–1916)

Crop	Acid phosphate	No fertilizer	Average increased yield from use of fertilizer
Corn	59.38 bu.	45.23 bu.	14.15 bu.
Wheat	14.17 bu.	7.83 bu.	6.34 bu.
Clover and timothy hay	4,020 lb.	2,360 lb.	1,660 lb.

Since acid phosphate seldom sells for more than $1 per hundred pounds, it can be readily seen that its use has paid well even when a

reasonable charge is made for distributing the fertilizer and handling the increased crop.

In a study of economy in the use of fertilizers, examples equally as striking as these may be found in the literature of the agricultural experiment stations of practically every state east of the Mississippi River, and results of experiments in the more recently developed western states also indicate that the use of fertilizers often pays well.

The Functions of Nitrogen, Phosphorus and Potassium.—Unfortunately much of the money spent for fertilizers is thrown away, not because fertilizers are valueless but because they are not judiciously used. In order to use fertilizers intelligently a farmer should know something of the functions of nitrogen, phosphorus and potassium.

Nitrogen.—Nitrogen increases growth and defers maturity. It produces a good leaf and stem development and gives to plants that luxuriant, dark green color which is so desirable in growing crops. An oversupply of nitrogen is indicated by a too great proportion of stem and leaf to fruit; and in small grains such an oversupply may cause a weakness of stem with resultant lodging and inferior grain. When a soil is poor in nitrogen, plants do not grow large and they usually have poor color. The result of too much nitrogen is very similar to that of large supplies of water, while the result of too little nitrogen is very similar to that brought about by drought. No matter how much phosphoric acid and potash there may be in the soil, the crops can use only quantities in proportion to the growth of the plants, and the growth of the plants will be in proportion to the nitrogen in the soil.

Phosphorus.—Phosphorus hastens maturity of crops, and aids in transferring substances from the stalk, leaves and other growing parts to the seed, making the grains plump and full. It increases the proportion of grain to straw, and also stimulates root development in young plants. An insufficiency of phosphorus is indicated by a too small proportion of grain to straw and by slow maturing of crops. Phosphorus is seldom found in soils in sufficient quantities to injure plants. In some soils phosphorus is probably more often the limiting factor in crop production than any other plant nutrient.

Potassium.—Potassium is essential to the formation of starch, sugar and cellulose; and where it is insufficient, plants do not mature well. It strengthens the stems; and the balancing effect which it seems to have on phosphorus and nitrogen causes better proportion of vegetative parts to fruiting parts. One of the most striking indications of an insufficiency of potassium is the early ripening or dying of the stems and leaves of plants while the seeds or fruit are still immature. Weak stems, when not caused by an overbalance of nitrogen, may indicate a lack of available potassium. Root crops respond readily to applications of potassium fertilizers and fail to do well when enough potassium is not available.

Why Fertilizers Are Necessary.—Practically all of our soils contain limited quantities of one or more of the essential plant nutrients. When crops are constantly removed and too little attention is given to maintaining the productivity of the soil, there finally comes a time when crop production is no longer profitable. Nitrogen may often be maintained and sometimes increased by the use of legumes; but when potassium and phosphorus are taken from the soil by constant cropping, the insufficiency of these elements must be met by the use of fertilizer applications. Commercial fertilizers are not merely soil stimulants; they are plant nutrients and are often the most economical source of these materials.

Fippin (1914) gives the following tables to show the amount of plant nutrients found in New York soils and the amount removed by the common crops.

Table XXIV.—Chemical Composition of Soils per Acre-foot

	Nitrogen, lb.	Potassium, lb.	Phosphorus, lb.	Calcium, lb.	Magnesium, lb.	Sulphur, lb.
A "normal" soil...	6,000	30,000	1,600	24,000	15,000	1,200
Volusia silt loam...	5,000	53,000	1,800	5,000	6,500	
Volusia loam.......	5,250	50,000	1,500	12,500	16,000	
Dunkirk clay loam.	7,000	60,000	3,000	22,000	10,000	

Table XXV.—Yield and Chemical Composition of Crops

Crops	Yield per acre	Nitrogen, lb.	Potassium, lb.	Sulphur, lb.	Phosphorus, lb.	Calcium, lb.	Magnesium, lb.
Corn, grain....	50 bu.	50.0	9.5	5.0	8.5	1.0	3.0
Corn, stover....	1.5 tons	24.0	26.0	2.0	3.0	10.0	5.0
Wheat, grain...	25 bu.	35.5	6.5	4.0	6.0	1.0	2.0
Wheat, straw...	1 ton	10.0	10.5	3.0	2.0	4.0	1.5
Oats, grain.....	45 bu.	25.0	7.0	3.0	6.5	1.5	2.0
Oats, straw.....	1.25 tons	12.0	27.0	3.0	3.0	6.0	3.0
Clover, hay....	2 tons	80.0	60.0	12.0	10.0	45.0	17.0
Alfalfa hay.....	3 tons	140.0	50.0	18.0	14.0	67.0	24.0
Potatoes.......	200 bu.	44.0	60.0	7.5	9.0	3.5	4.0

The soil is the source of the plant nutrients mentioned; and as compared with the nutrients removed by any crop in a single year, the amount in the soil is large. In fact, it would seem practically impossible

to exhaust the calcium and potassium. However, the data in Table XXVI from Fippin (1914) show that a few decades of farming may exhaust these soils as far as nitrogen and phosphorus are concerned.

TABLE XXVI.—MAXIMUM NUMBER OF CROPS THAT COULD BE PRODUCED BY THE AMOUNT OF EACH OF THE PRIMARY PLANT NUTRIENTS IN AN ACRE-FOOT OF "NORMAL" SOIL

Crop	Yield per acre	Nitrogen	Potassium	Phosphorus	Sulphur	Calcium	Magnesium
Corn	50 bu. grain and stover	80	860	133	172	2,182	1,875
Wheat	25 bu. grain and straw	133	1,765	200	171	4,800	4,300
Oats	45 bu. grain and straw	162	882	168	200	3,200	3,000
Clover hay	2 tons	75	500	160	100	533	882
Alfalfa hay	3 tons	45	600	115	70	373	625
Potatoes	200 bu., 2 tons tops	136	500	177	160	6,860	3,750

These figures are for the surface foot of the "normal" soil and there are many other feet of soil below which contain plant nutrients that may become available in time, when brought under the influence of weathering agencies. However, these soils would probably become unprofitable for crop production long before the number of crops indicated had been grown, if nothing were done to maintain the supply of nutrients in the soil, as much of the plant nutrients in any soil is in an unavailable form. Because of this unavailability, fertilizers often give profitable returns when chemical analyses show an abundance of the essential elements in the soil.

Factors and Theories Relative to Fertilizer Application.—The primary object in the use of fertilizer is to obtain a profit from the increase in yield of crops from the land on which the fertilizer is applied. There are a number of factors which have either a direct or an indirect influence upon the profits that may be obtained from the use of fertilizers. A few of the more important of these are: (1) soil type; (2) weather conditions; (3) crop grown; (4) productivity of the soil; and (5) length of growing season.

Soil Type.—It is a well-known fact that soils differ widely both in their chemical composition and in their physical properties, both of which have a direct influence on the effects of any specific fertilizer application. For example, clay soils have the ability to retain certain fertilizer materials while sandy soils are not very retentive of plant nutrients and are more subject to the bad effects of leaching. Obviously, the effects

of the same amounts of fertilizer on these different soil types would be dissimilar even though the soils showed the same chemical content of plant nutrients. From a chemical standpoint sands consisting largely of quartz are usually much lower in plant nutrients than clays which are made up of a number of minerals.

Weather Conditions.—Weather conditions may affect the profits from fertilizers because the condition of the weather often becomes the limiting factor in plant growth. No amount of plant nutrients can increase crop yields if there is not sufficient moisture, nor can profits be made from the use of fertilizers when the growth of crops is limited by excessive moisture. Thus it is seen that if the weather is unfavorable, no profits may be obtained from the use of fertilizer.

Character of Crop.—The financial result from the application of fertilizer is also influenced by the character of the crops grown. Voorhees (1916) classifies crops into two general groups: (1) those which remove a comparatively large amount of fertilizer constituents from the soil, and which, as a rule, possess a relatively low commercial value, and (2) those which remove comparatively small amounts of fertilizer constituents from the soil and have a relatively high commercial value. In the first group are included such crops as the cereals and forage crops, and in the second, vegetables and fruits. As a general rule, crops which have a high acre value give larger returns from the use of fertilizer than do crops of low acre value.

Productivity of the Soil.—The profit obtained from the use of fertilizers is also greatly influenced by the natural productivity of the soil. An example may be seen in the fact that certain soils of the East which have been cropped for generations cannot be farmed profitably without fertilizers. Crops grown on such soils usually respond to the use of commercial fertilizers. However, some of the soils of the West which have been farmed only about fifty years do not give profitable returns from the use of fertilizers.

Length of Growing Season.—Wolfe (1919) in Virginia has shown that the right proportion of nitrogen, phosphorus and potassium in the soil has a marked influence upon the time of maturity of the corn crop. Thus the addition of fertilizing materials to bring about the proper proportion of nutrients may hasten maturity, and, with certain crops, thereby increase profits. In localities where seasons are short, fertilizers may be used to hasten maturity, even when they do not increase crop yields.

Systems of Fertilizing.—Owing to the fact that there are so many factors which influence the results to be expected from the use of fertilizers, it is impracticable to attempt to give information concerning the use of fertilizers that will apply equally well under all farming conditions. However, there have been a number of fertilizing methods or systems suggested, each of which possesses some merit.

A System Based upon the Influence of a Single Element.—This system assumes that as far as fertilizing is concerned crops may be divided into three groups: (1) plants especially benefited by nitrogen, (2) plants especially benefited by phosphorus and (3) plants especially benefited by potassium. In this system it is asserted that nitrogen is the dominant ingredient for wheat, rye, barley, grass and oats; phosphorus for turnips, corn, sorghum and sugar cane; and potassium for peas, beans, clover, flax and potatoes. This system does not advocate the use of single elements only but requires that the dominant element for a certain group be the dominant ingredient of the fertilizer used for the crops of that group. In the case of soils of high productivity the specific element for the group may be used simply to force a maximum crop growth. Thus, specific fertilizing is arranged for the various rotations, the crop receiving that which is most useful. The chief objection to this system is that it cannot be depended upon to give results where the soil is in a low state of productivity.

A System Based upon the Necessity of an Abundant Supply of the Minerals.—This system requires that the mineral elements, phosphorus and potassium, which do not readily leach out of the soil, be maintained in an available form in amounts much greater than are required to meet the immediate needs of plants. Nitrogen, which is more readily lost from the soil, is to be applied in active forms, in such quantities, and at such times as will insure maximum yields. This system is useful in building up unproductive soils quickly and in increasing the production of crops which give large financial returns to the acre.

A System Based on Chemical Analysis of Plants.—This system is based on the theory that the different plants should be provided with nitrogen, phosphorus and potassium in the proportions in which they exist in plants, as shown by chemical analyses. It does not take into consideration the amount of plant nutrients already in the soil, or the difference in ability of different types of plants to secure their nutrition from the soil. The method may be applied to greenhouse work or in growing market garden crops, but it is usually not economical for use in the production of ordinary field crops.

A System in Which Fertilizer Is Applied Only to the "Money Crop" in the Rotation.—In this system the crop in the rotation which gives the largest money returns per acre receives a heavy application of fertilizer. The application is in excess of the immediate needs of the crop and the other crops in the rotation use the residue left by the money crop. This system is often used with such crops as potatoes and tobacco which require, for best returns, an excessive amount of available plant nutrients in the soil. For example, a tobacco crop may receive an application of 2,000 pounds of a fertilizer carrying 4 per cent nitrogen, 8 per cent phosphoric acid and 4 per cent potash. This quantity is considerably more

than an ordinary crop of tobacco will use and there is, therefore, a considerable residue left in the soil which may be used by the succeeding crops. This method possesses many valuable features, and is, perhaps, as good as any other to use in field crop production.

There are good features in all of these systems and it rests with the farmer to use that which in his judgment applies best to his conditions. These systems do not take into consideration differences between soils in their physical and chemical relations nor do they take cognizance of the benefits to be derived from such practices as green manuring and liming. Perhaps the best systems to be practiced are those which are recommended by the state experiment stations or which are being used successfully by neighboring farmers.

CHAPTER XII

BARNYARD MANURE

Barnyard manure was one of the first materials used on the soil for the purpose of increasing productivity. Before the time of Christ, Virgil wrote: "Sprinkle sordid ashes all around and load with fattening dung thy fallow ground." The fact that many other early writings refer to the use of barnyard manure leaves little doubt that the benefit derived from this material was recognized by our earliest farmers. However, new countries rarely appreciate the value of barnyard manure. It is not until the productivity of the soil has begun to decline that manure is given the attention that its value justifies. In comparatively recent years, it was not an uncommon sight to see manure on American farms being drawn to the nearest ditch or stream for the simple purpose of getting it out of the way, and many ranchers would have welcomed the services of a Hercules to clean their barns of the accumulations no less undesirable than those of the Augean stables.

Effects of Manure.—The results obtained from the use of manure vary with the locality, soil and crop. However, the results of experiments in various parts of the United States show that its application gives paying results in practically every locality. As a result of experiments conducted at the New York (Cornell) Experiment Station, where various fertilizing materials were applied to timothy and their residual effect studied on the corn crop which followed, Lyon and Morgan (1910) say: "The residual effect of barnyard manure was greater than that of any combination of artificial fertilizers. Ten tons per acre show an increase of 110 per cent in ear corn and 20 tons per acre an increase as high as 115 per cent." Harris (1920), working on irrigated soils in Utah, found that a 10-ton application of manure increased the yield of sugar beets about 10 tons to the acre, that 5 tons of manure increased the yield of potatoes 65 bushels to the acre and that a 5-ton application of manure increased the yield of wheat 10 bushels to the acre. Hutcheson and Wolfe (1919) report that at the Virginia Experiment Station an application of 4 tons of manure annually through an 8-year period gave an average annual increase of 20.29 bushels of corn, 10.48 bushels of wheat and 1.27 tons of hay to the acre. Williams and Welton (1915), at the Ohio Experiment Station, found that the yield of corn, based on an 8-year average, was increased 31.27 bushels per acre by the application of 8 tons of barnyard manure.

Many such examples of the increase in yields of crops from the use of barnyard manure might be quoted, but these are sufficient to illustrate its high value from a crop production standpoint.

Economy in the Use of Manure and Relative Value for Different Crops.—All common field crops respond to applications of barnyard manure and the returns are usually profitable. However, there are some indications that in a given rotation higher returns are obtained when the manure is applied to one crop than to other crops. In general, the crop which gives the highest money returns per acre gives the best profits from the use of manure. In the case of truck crops it often pays to make heavy applications of manure to each crop grown in the rotation. In general farming, the convenience of application is often as important as the relative profit to be obtained from the different crops.

Manure can usually be more conveniently hauled and distributed during the winter months, but lands are likely to be wet during the winter and cultivated fields are too muddy to drive over, except when frozen. In this case it is often economical to apply manure to the grass crop in the rotation even though some other crops in the rotation might give a higher return from its use. Where hay has a relatively high value, it may give a larger return from the use of manure than other crops in the rotation. Hopkins and others (1908) in Illinois found that manure applied to corn and oats gave an increase of 11 per cent in yield and an increased crop value of $7.53, while manure applied to clover increased the yield 92 per cent and increased the crop value $10.08.

It is not advisable to apply manure which contains much coarse material, such as corn stalks, to hay fields, as these materials may remain on the field and be raked up with the hay, in which event the quality of the hay would be reduced. Such coarse manures should be plowed under before crops such as corn and sorghum are planted, since these crops seem to have the ability to use these coarse materials to good advantage.

On soils which are low in organic matter and nitrogen, manure may be used advantageously as a top-dressing to small grains and it is particularly valuable for spreading on thin, eroded spots in such fields. However, manure should not be used as a top-dressing on small grain fields known to be rich in nitrogen as its relatively high nitrogen content may have a tendency to weaken the straw. Falling down or "lodging" might then result. Fresh manure is not advocated for potatoes, as it has a tendency to increase scabbiness, if the spores of the scab disease exist in the soil or on the tubers planted.

In general farm practice, special crops of high acre value usually receive first consideration in the use of manure. If more manure is available than is needed for such crops, it is often applied to the corn crop or is hauled out during the winter and scattered on the hay or pasture fields.

Time and Rate of Application.—As intimated in the previous paragraph, manure is usually hauled out when such work does not conflict with the more pressing work, such as seeding, cultivating and harvesting. Numerous experiments have been conducted to determine the value of manure applied during the winter months and plowed into the soil in preparation for a summer crop, as compared with manure applied on the plowed land in the spring and harrowed into the soil. The evidence from these experiments is conflicting but the differences in results are small in all cases and experimenters usually agree that convenience of application is of greater importance than time of application.

The rate of application of manure varies with the kind of crop to which it is applied. With crops of high acre value very heavy applications are usually advised. With truck crops, 30 tons or more to the acre may often be used to advantage. In general farming, light applications have usually given higher returns per ton of manure than heavy applications.

The results secured by Thorne and others (1912) in Ohio and shown in Table XXVII illustrate this point.

Table XXVII.—Increased Yield to the Ton When Manure Is Applied in Different Amounts at the Ohio Experiment Station

Amount applied	Wheat, bu.	Clover, lb.	Potatoes, bu.
4 tons to the acre	1.34	177	3.81
8 tons to the acre	.94	150	2.79
16 tons to the acre	.70	99	2.76

Harris (1920) at the Utah Experiment Station found that a 10-ton application of manure to sugar beets gave an increased yield of about 1 ton of beets for each ton of manure. Five tons to the acre gave nearly 2 tons of beets for each ton of manure; but where there was an application of as much as 40 tons to the acre, the increase was only about 0.4 of a ton of beets for each ton of manure. Where potatoes were manured at the rate of 5 tons to the acre, the yield was increased by nearly 13 bushels for each ton of manure; but where 40 tons were applied, the increase was only 4.3 bushels for each ton. In the case of corn, a 5-ton application of manure gave an increase of 3.83 bushels for each ton of manure and a 15-ton application gave only 1.61 bushels of grain for each ton of manure.

One of the great advantages of the modern manure spreader is that it will scatter small quantities of manure evenly over the soil. Since it is possible in this way to manure more of the farm each year with the

limited quantity of manure at hand, the farmer receives a larger return for each ton of manure applied.

Factors Influencing the Value of Barnyard Manure.—The value of manure varies considerably according to the kind and age of animals, the kind and amount of food consumed, the kind and amount of bedding used and the system followed in collecting, preserving and utilizing the manure.

Class of Animals.—The results shown in Table XXVIII, taken from the work of Taliaferro and Patterson (1907) at the Maryland Agricultural Experiment Station, show the average yield and composition of fresh excrement from different kinds of animals.

TABLE XXVIII.—SHOWING AVERAGE YIELD AND COMPOSITION OF FRESH EXCREMENT FROM FARM ANIMALS

Kind of animal	Excrement per year, lb.	Composition			
		Water, per cent	Nitrogen, per cent	Phosphoric acid, per cent	Potash soda, per cent
Solid excrement:					
Cows	20,000	84.0	0.30	0.25	0.10
Horses	12,000	76.0	0.50	0.35	0.30
Pigs	1,800	80.0	0.60	0.45	0.50
Sheep	760	58.0	0.75	0.60	0.30
Hens	35	48.6	1.38	0.50	0.41
Liquid excrement:					
Cows	8,000	92.0	0.80	trace	1.4
Horses	3,000	89.0	1.20	trace	1.5
Pigs	1,200	97.5	0.30	0.12	0.2
Sheep	380	86.5	1.40	0.05	2.0

It will be observed from this table that there is a considerable variation in the quality of the excrement from the various animals and that in most cases the liquid excrement is quite as valuable as the solid excrement from a plant nutrition standpoint.

Food Consumed.—The fertilizing value of the excreta is derived from that of the food consumed and varies accordingly. Bartlett (1906) in Maine showed that the value of the nitrogen, phosphorus and potassium recovered in the excreta from 100 pounds of various kinds of feed fed to steers was, for hay 21.93 cents; spring wheat bran, 58.64 cents; and cottonseed meal, 118.30 cents. The valuation figures used in arriving at these figures are not given but this does not affect the comparison.

The amount of feed consumed also has a considerable influence on the value of the manure produced, as animals on a scant ration digest their food much more thoroughly than those receiving a full feed.

Bedding Used.—Since materials used as bedding for animals vary in chemical composition, it is obvious that the character of the bedding will influence the composition of the manure obtained. For example, when bean straw is used for bedding, the manure will be richer in nitrogen than if the same amount of sawdust is used, because the former contains more nitrogen.

Care of Manure.—The liability of manure to a rapid loss of its constituents makes proper care and handling of the material an extremely important consideration. The richer the original manure is in nitrogen, phosphorus and potassium, the greater is the liability to loss. This tendency is due to the more rapid fermentation of a substance rich in nitrogenous materials and to the greater possibility of loss from leaching in substances containing large amounts of soluble mineral salts.

That manure loses in value very rapidly when exposed to the weather is shown by the work of Voorhees (1901) at the New Jersey Experiment Station. Solid and liquid cow manure combined, exposed for an average of 109 days, lost 51 per cent of its nitrogen, 51.1 per cent of its phosphoric acid and 61.1 per cent of its potash. This loss is not entirely preventable but can be greatly reduced by proper care. Due to fermentation and leaching, considerable loss of manure occurs in the barn, which can be reduced by keeping the floors well bedded with some material that has high absorbent properties. Such material should be supplied in sufficient quantities to absorb all liquids and keep the animals clean. Too much litter, while it does not reduce the actual value of the excrement, dilutes the manure with material which often does not carry large quantities of fertilizing ingredients. The next consideration in the care of manure is a tight floor. Thorne (1907) of Ohio found that 12.3 per cent more nitrogen and 9.4 per cent more potash were recovered in manure produced on cement floors than from manure excreted on earth floors.

Where feasible, it is advisable to haul manure to the field as soon as it is produced. Manure scattered on fields loses very little from fermentation and when leaching occurs the soluble portions of the manure are carried directly into the soil. It is not always convenient to haul manure directly to the field and in most cases storage must be provided.

Storing Manure.—The two fundamental requirements for the proper care of manure are to prevent leaching and to minimize the loss of nitrogen from fermentation. These two ends are best obtained by storing the manure in covered sheds with tight bottoms and keeping it carefully spread and moistened. Where covered sheds with tight bottoms can be provided for live stock, the loss in manure can be reduced to a minimum. Leaching is prevented by the roof and tight floor, the trampling of the

animals keeps the manure compact, and the urine furnishes moisture which reduces fermentation. Frear (1903) in Pennsylvania has shown that untrampled manure in covered sheds loses more than three times as much of its fertilizing value as trampled manure in covered sheds.

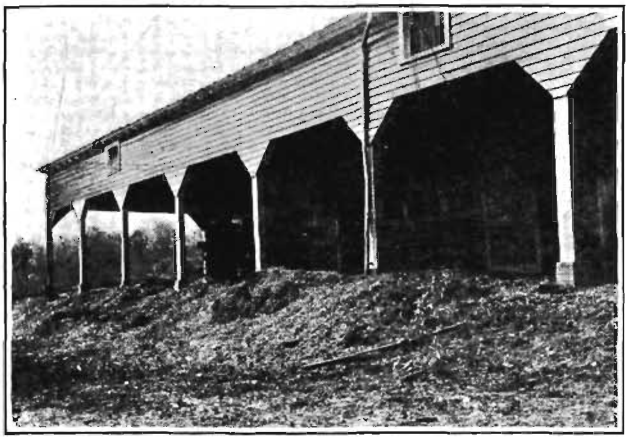

Fig. 9.—Improper handling of manure; subject to much leaching.

When covered sheds are impracticable, the next best method of storing manure is in covered concrete pits. Both the solid and the liquid excrements are stored in these pits until it is convenient to haul them to the

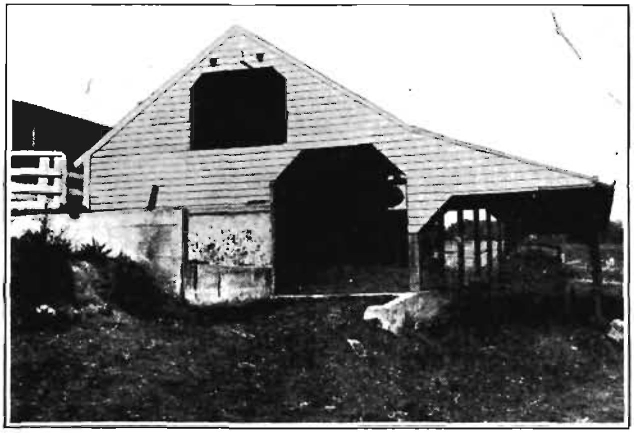

Fig. 10.—Proper care of manure; covered concrete manure pit.

field. The manure should be well packed in such pits and sufficient moisture should be provided to prevent heating. The most wasteful method of storing manure is in piles fully exposed to the weather. However, it is often necessary to expose manure to the weather; and when such is the case, an excavation should be made where the pile is to be

located so that the drainage will be toward rather than away from the heap. The sides of the pile should be steep so as to shed water rapidly and each addition of manure should be firmly packed. In dry weather the manure should be moistened to prevent burning and the pile should be hauled to the field as soon as practicable.

Well-rotted manure is often desirable for trucking and gardening. Manure loses a large amount of its fertilizing value in the rotting process, but the resulting product is relatively richer in plant nutrients than fresh manure, because rotting reduces the total weight of the manure more rapidly than it reduces the fertilizing constituents. Thus well-rotted manure is a more concentrated product than fresh manure. Care should be taken to keep manure which is undergoing the rotting process moist and well packed, so as to reduce loss as much as possible.

How Manure Increases Crop Yields.—Manure increases crop yields probably for the following reasons: (1) It carries a considerable quantity of elements necessary for plant growth which are often insufficient in the soil; (2) it adds organic matter to the soil; and (3) it increases the bacterial content of soils.

Source of Plant Nutrients.—According to Taliaferro and Patterson (1907) mixed barnyard manure contains, on an average, about 0.5 per cent of nitrogen, 0.3 per cent phosphoric acid and 0.4 per cent potash. These amounts seem small when manure is compared with high-grade commercial fertilizers; but when the enormous amount of manure produced by the ordinary farm animals in a year is considered, the total quantity of plant nutrients produced reaches a relatively high figure. Hart (1912) states that the amount of manure produced per day per 1,000 pounds of live weight of different animals is as follows: sheep 34.1 pounds, pig 56.2 pounds, cow 74.1 and horse 48.8 pounds. He further states that with these weights of manure the animal excrement from 1,000 pounds live weight of animals would be worth annually $26.09 for sheep, $37.96 for pigs, $29.27 for cows and $27.74 for horses. Unfortunately, manure depreciates rapidly in value when not properly cared for and few farmers obtain the value from the manure of their animals that these figures indicate as possible.

It should be noted that manure is not a well-balanced fertilizer, being rather low in phosphorus and relatively high in nitrogen and potassium. As many soils are poor in phosphorus, the efficiency of manure is often increased by the addition of phosphate fertilizers. Duley (1919) in Missouri reports that the addition of 400 pounds of acid phosphate, analyzing 16 per cent phosphoric acid, to an 8-ton application of barnyard manure once in a 4-year rotation of corn, soybeans, wheat and clover increased the corn yield 3.73 bushels, soybean hay 477 pounds, wheat 4.92 bushels and red clover hay 1,077 pounds to the acre, respectively. At the then current prices the increased yield due to the reinforce-

of the manure amounted to $16.48. Thorne and Hickman (1902) report similar results from the Ohio Experiment Station.

Source of Organic Matter.—Manure contains a high percentage of organic matter but under ordinary conditions only a comparatively small proportion of its organic matter is returned to the land when manure is applied. However, since all of the organic matter is produced from materials which come from the atmosphere, the organic matter which is returned to the soil can be counted as a real addition to the soil. Therefore, manure is considered an important source of organic matter.

Source of Bacteria.—Temple (1911) in Georgia found that the addition of cow manure to the soil greatly increased the bacterial content and that this increase continued over a considerable period. Brown (1913) in Iowa also found that the application of manure, up to 16 tons to the acre, increased the number of organisms in the soil.

CHAPTER XIII

LIME

The practice of applying lime to the soil is very old, probably extending back many years before the Christian Era. It, however, did not receive much attention in the United States until the last quarter of a century. The introduction of commercial fertilizers about the middle of the nineteenth century with the emphasis placed on their ability to supply certain plant nutrients diverted attention from the use of lime.

Lime Defined.—The different forms of lime from an agricultural standpoint, are the oxide, hydroxide and carbonate of calcium or magnesium. Lime, in any of its forms, practically always carries magnesium as well as calcium, the latter usually predominating. Calcium sulphate or gypsum is sometimes classified as a form of lime; but since its functions in the soil are somewhat different from those of the first-mentioned group of calcium and magnesium salts, it will not be considered here. Lime is usually called a soil "amendment" rather than a fertilizer, as it does not carry nitrogen, phosphorus or potassium. Lime frequently makes it possible to use more commercial fertilizers with profit.

Commercial Forms of Lime.—The commonly used commercial forms of lime are: (1) burnt lime; (2) water-slaked lime, commonly called "hydrated" lime; (3) ground limestone; (4) ground shells; and (5) marls. All of these materials are useful for agricultural purposes but vary to a certain extent in effectiveness. Burnt lime, calcium oxide and magnesium oxide, is the most concentrated form of lime. MacIntire (1916) has shown that burnt lime is changed into the carbonate form very rapidly when applied to the soil. This change is brought about by the taking up of carbon dioxide; it takes 44 pounds of carbon dioxide to convert 56 pounds of calcium oxide into the carbonate form. Thus, 1 ton of pure burnt lime will produce, 3,571 pounds of calcium carbonate. Since limestones are seldom pure, it can be seen from these figures that 1 ton of burnt lime is approximately equivalent to 2 tons of calcium carbonate. Water-slaked lime, calcium hydroxide and magnesium hydroxide, are made by water-slaking burnt lime. From 56 pounds of pure burnt lime 74 pounds of water-slaked lime may be yielded. Therefore, 1 ton of burnt lime is approximately equivalent to 1½ tons of water-slaked lime.

Ground limestone and marls, with the exception of the shell marls, are carbonates of calcium or magnesium. The shell marls and ground shells are carbonates of calcium. These materials are usually, but incorrectly, spoken of as carbonates of lime. There has been much con-

troversy in the past as to the relative values of these different forms of lime. From a theoretical standpoint, 1 ton of burnt or quicklime is approximately equivalent to 1½ tons of water-slaked lime or 2 tons of the carbonate.

Form of Lime to Use.—Unpublished data from the Virginia Experiment Station show practically the same results from the application of an equivalent quantity of calcium oxide to the soil, without regard to the kind of lime used, whether burnt lime, ground limestone or marl.

Bachtell (1913) recommends for Ohio conditions the use of lime at the rate of 1 ton of burnt lime or 2 tons of ground limestone. Miller and Krusekopf (1917) of Missouri say, "The kind of lime to use should be determined almost entirely by the kind which gives the greatest sweetening power for a dollar invested." Similar recommendations are given by the majority of experiment stations of the United States reporting on the relative value of different forms of lime. However, Hopkins (1907) in Illinois strongly recommends the use of ground limestone in preference to burnt lime.

Location of Farm as Affecting Economy in Forms of Lime.—In the choice of a liming material, distance from the railroad station is often an important consideration. Concentrated materials such as burnt and water-slaked lime are more costly to buy but are less costly to haul and spread per unit of available oxide and are needed in less quantity per acre. Coarse carbonate materials, such as screenings and coarsely ground limestone, on the other hand, have a cheaper initial cost but a high hauling and spreading expense. Consequently, the latter may prove more economical close to the source of production. For reverse reasons concentrated materials such as burnt lime and water-slaked lime often prove cheapest on outlying farms. Intermediate goods such as finely ground limestone and marl of high purity, and the lower grades of burnt and water-slaked limes fall between these extremes.

Bear of Ohio suggests that the coarser materials may be economical within a 1-mile zone of the railroad station. The economy zone for pulverized limestone is placed by him at 1 to 5 miles, while burnt limes fall within the outer zone ranging from 5 to 10 miles or more. These divisions are not absolute but merely serve to point out the range of distribution as influenced by concentration.

From a farmer's standpoint the most important consideration in reference to forms of lime is the cost of a given quantity of available oxides spread on the land. In arriving at the price of lime applied to the land, one must consider all costs including freight, wagon hauling and spreading.

Fineness of Ground Limestone.—White (1917), in Pennsylvania, Hutcheson and others (1917) in Virginia, and Frear (1921) in Pennsylvania all report higher crop yields from the use of very finely ground

limestone than from coarser materials. However, these experiments were of short duration and tests covering a longer period may possibly give different results. Very finely ground limestone is produced at a greater cost than the coarser materials and in some cases it is economical to buy the coarser materials even though they may be less available and less efficient from a crop production standpoint. White says: The increased cost of the very finely ground limestone, together with the rapidity with which it disappears from the soil as compared with coarser material, leads to the conclusion that an application of material all of which will pass a 10-mesh screen and include all of the fine material incident to such grinding is sufficiently fine for soil improvement if applied somewhat in excess of the immediate need of the soil."

A number of other agricultural workers report that limestone ground fine enough to pass a 20-mesh screen is sufficiently fine for agricultural purposes, if none of the finer particles incident to the grinding are removed before applying.

Rate of Applications.—No definite rule can be given as to the amount of lime to apply. This will depend upon both crop and soil. It is obvious that crops requiring large quantities of lime planted on very acid soils should receive more lime than less exacting crops on soils with a comparatively low lime requirement. Lime may be applied in sufficient quantities to meet the lime requirement of the soil as determined by chemical tests. However, good results are often obtained from the use of much smaller quantities than are necessary to meet the lime requirement as determined by these tests. The rule followed by many farmers is to apply 1 ton of burnt lime or its equivalent to the acre on clay soils and half this amount on sandy soils.

Time and Method of Application.—To be most effective, lime should be thoroughly mixed with the plowed portion of the soil. This mixing is usually done most economically by broadcasting lime on newly plowed land and mixing it with the soil by the disking and harrowing necessary to prepare the seedbed. However, economy in hauling may have an important influence on the method of application. It is often more convenient to haul lime during the winter or at some other season when other farm work is not pressing. Sometimes land has not been plowed at these seasons; and if the lime is hauled, it must either be stored or spread on unplowed land. In recent years many farmers have followed the practice of hauling lime when convenient and spreading on the fields where needed, whether they have been plowed or not. Even when lime is spread and plowed under, it has given satisfactory results. In some cases lime is spread on winter grains after seeding. This practice has proved desirable when it is not practicable to apply the lime before seeding, especially when clover is to be seeded on the grain land the following spring. The time of application is often immaterial and in

farm practice is usually determined by the distribution of labor. The place in the crop rotation should be usually just before the crop most responsive to lime, provided this time is convenient and does not interfere with economy in the use of labor. When it is not possible to apply lime at this time, it may be applied to some other crop in the rotation.

Frequency of Application.—The frequency of application depends somewhat upon the rate of application. Thorne (1918) found that when lime was applied at the rate of 1 ton to the acre to Ohio soils, the application should be repeated in from 6 to 8 years. It has been suggested that lime be used in sufficient quantities to meet the lime requirement of the soil when used for the first time, and *that thereafter smaller quantities* be used once in each rotation course, depending upon the length of the rotation.

Effect of Lime on Different Crops.—That an application of lime may not effect all crops alike is well known. Mooers (1913) of the Tennessee Experiment Station has grouped some of the common field crops according to their response to liming. The grouping is shown in Table XXIX.

TABLE XXIX.—EFFECT OF LIMING ON VARIOUS CROPS ACCORDING TO TRIALS MADE ON COMMON UPLANDS IN THE STATE OF TENNESSEE

Crops which were practically a failure without liming	Crops decidedly helped	Crops moderately helped	Crops little affected	Crops injured
Alfalfa	Crimson clover	Timothy	Redtop	Cotton
Alsike clover	Cowpeas	Kentucky bluegrass	Rhode Island bent	Peanuts
Red clover	Soybeans	Tall oat grass	Sweet vernal	Watermelons
White clover	Velvet beans	Meadow fescue	Sheep's fescue	
	Hairy vetch	Italian rye grass	Rye	
	Garden beets	Corn	Tobacco	
	Cantaloupes	Sorghum	Strawberries	
	Cucumbers	Barley	Sweet potatoes	
	Summer squash	Wheat	Potatoes	
		Oats	Egg plant	
		Millet	Lima beans	
		Orchard grass	Stringless snap beans	
		English rye grass		
		Bromus inermis		
		Bermuda grass		
		Rhodes grass		
		Sudan grass		
		Tomatoes		
		Pepper		
		Japan clover		

These results, though differing in some respects, correspond rather closely to those of Hartwell and Damon (1914) at the Rhode Island Experiment Station. That some differences should appear is not surprising as the soils in Rhode Island differ in several important respects from those of Tennessee. At the Tennessee Experiment Station, cowpeas are placed in the group of crops which is benefited by the use of lime, while in Rhode Island they are placed in the group which is injured by the use of lime. According to unpublished results from the Virginia

FIG. 11.—Showing the effects of lime on soybeans. The plat on the right received lime at the rate of 1 ton of burnt lime to the acre; the plat on the left received no lime. Note that the soybeans on the unlimed plat are beginning to shed their leaves, while those on the limed plat are still green and luxuriant.

Agricultural Experiment Station, sweet clover should be classified as a crop which fails on very acid soils. Peanuts have also responded to the use of lime on the sandy soils of eastern Virginia. There has been but a slight increase in yield, but a decided improvement in quality where lime was used.

The statement that tobacco and potatoes should not be classified as crops little affected by lime needs a word of explanation. In most experiments tobacco gives some increase in yield from the use of lime; but in certain types of tobacco, such as the bright tobacco of Virginia and the Carolinas, quality is greatly reduced by lime applications. Disease-free potatoes are not injured by the use of lime but lime has a tendency to increase scab on potatoes, if the tubers or soil are infected with the scab organism. Consequently, when scab is present, the yield of marketable potatoes may be greatly reduced by lime applications.

Corn is classified by Mooers (1913) in Tennessee as a crop moderately affected by lime. However, Hart (1919) in Virginia has shown that when corn was grown in a rotation with tobacco, wheat, and clover, the profits from the use of lime were greater in the case of corn than for any other crop in the rotation. This result may have been due to the fact that clover grew better on the limed plats and thereby furnished organic matter and nitrogen, a circumstance which was really responsible for the increased yields of corn.

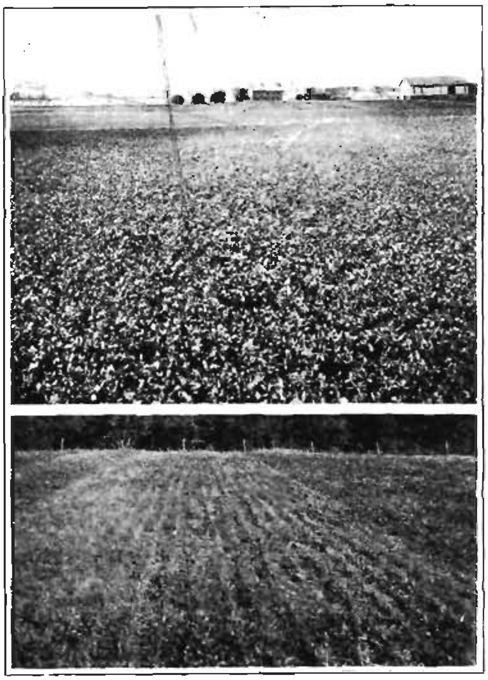

FIG. 12.—Effect of lime on clover at the Ohio Experiment Station, Wooster, Ohio. Limed area above and unlimed area below.

It would seem from the foregoing discussion that the profits from the use of lime depend upon the condition of the soil and the crops grown. If soils are poor in bases, lime will give profitable returns on all of the most important crops of the United States, with the probable exception of cotton and potatoes. The two last-mentioned crops may be indirectly benefited by the use of lime when grown in rotation with clovers and other legumes.

The clovers are greatly benefited by the use of lime; and when the soil is limed, they add more organic matter and nitrogen to the soil. The use of lime usually makes it easier to produce good crops of clover. Where clovers can be grown successfully, most adapted crops

thrive. Many of the beneficial effects commonly attributed to lime are really directly due to the growth of clover made possible by the use of lime.

Benefits from the Use of Lime.—Most soils contain sufficient calcium for the nutrition of plants, but even in view of this fact lime is frequently applied. In addition to supplying calcium, lime aids in bringing about changes in soils that make them more suitable for the growth of crops and as a result crop yields are frequently increased. Lime has, according to Shorey (1918), the following effects when applied to the soil: (1) correction of soil acidity; (2) improvement of the physical condition; (3) stimulation of the proper decomposition of organic matter; and (4) probable increase in availability of other minerals in the soil.

Indications of the Need of Lime.—The first symptoms of soil acidity are the partial or complete failure of those crops, common to the locality, most sensitive to soil acidity and the encroachment on the land of acid-tolerant species of weeds and grasses. Gardner (1921) states that sorrel, wild daisies, yellow trefoil, poverty grass and dewberries are common weed indicators of soil acidity in Pennsylvania, and that paint brush, sheep sorrel, corn spurry and wood horsetail are indicators of acidity in other parts of the country. To this list may be added redtop, broom sedge, the bent grasses and the plantains. The failure of such lime-loving plants as red clover, sweet clover and alfalfa may also be considered an indication of the need of lime, if other soil conditions are right.

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CHAPTER XIV

SEEDING PRACTICES

The term "seeding" as used here refers to all methods of planting regardless of whether the crop is reproduced by seed or by vegetative parts. Most of the field crops, such as corn, wheat and oats, are propagated from seeds, while others, such as potatoes, sugar cane and some of the grasses, are propagated from vegetative parts.

Relation of Seeding Practices to Kind of Seeds.—It is a well-known fact that seeding practices vary with the kind of crop. Generally speaking, grasses, clovers, alfalfa and the small grains are seeded broadcast or in closely spaced drill rows. Corn, potatoes, cotton, tobacco, beans, sorghum and all other crops which require inter-tillage are planted in rows far enough apart to admit the passage of ordinary tillage implements, or even wider, if the growth of the plants makes it necessary. There are, however, some exceptions to this rule.

Plant breeders and other workers who desire to rapidly increase the progeny of a new strain often sow small grains in rows sufficiently far apart to admit of cultivation. The practice of sowing oats in rows wide enough for subsequent cultivation has been practiced to a limited extent in certain parts of the South but the method is not generally followed in any locality and seems to be waning in popularity.

Relation of Seeding Practices to Kind of Vegetative Parts.—Bermuda grass may be propagated from seed but the common practice is to plant root cuttings or pieces of sod. The latter method is surer and more satisfactory where conditions are not favorable for the production of seedlings. Carrier (1922) recommends the planting of lawn grasses as follows: Stolons of lawn grasses which will root at the joints, such as Bermuda grass, carpet grass and creeping bent, should be cut into pieces 2 or 3 inches long and scattered broadcast. The cuttings should then be covered with about a half-inch of soil.

Sugar cane is planted by laying stalks in furrows and covering them with soil. Shoots which develop into canes are put out at each joint. Certain crops which can be transplanted easily are often started in plant beds and afterwards set in the field. Tobacco, tomatoes and cabbage are good examples of this group.

Sweet potatoes are usually propagated by planting the roots close together in a hot bed and, when the shoots are large enough drawing out the plants for setting in the field. In sections where the season is long

enough, cuttings made from the plants which were grown in the hot bed are used to plant additional acreage. The crop grown from these cuttings is recommended for seed purposes as the cuttings may be taken from healthy plants. Potatoes and Jerusalem artichokes are propagated from tuber cuttings.

Relation of Seeding Practices to Quality of Seeds.—When seeds of poor quality are used, it is usually advisable to increase the rate of seeding in order to insure good stands. If germination is low, a sufficient quantity should be seeded to insure the proper amount of viable seed to the acre. If seeds are sown which will germinate but are otherwise low in quality, enough seed should be seeded to allow for the thinning out of the poorer plants, either by hand or by natural selection.

Montgomery (1912) in Nebraska has shown that when large and plump seeds are sown in competition with smaller, poorly developed seeds there is a tendency for the progeny of the inferior seeds to be eliminated. This is particularly striking where seedings are thick. Thus when seeds of poor quality are sown thickly, the weaker plants will be crowded out. The same author has shown that corn may be improved by planting thickly and pulling out the weak plants. However, inferior seeds should not be used if this can be avoided, for even when sown thickly, uneven stands may be obtained.

Relation of Seeding Practices to Climate and Season.—Generally speaking, the hardier strains and varieties of crops give best results in rigorous climates. It has been found that clover seeds imported from southern Europe produce plants which are not nearly so resistant to winter-killing in the northern part of the United States as native-grown strains. The introduction of Grimm alfalfa, a very cold-resistant variety, into Minnesota and the Dakotas has made it possible to grow alfalfa successfully in many sections where other kinds were very uncertain. Cold-resistant varieties of wheat have also been developed which have greatly increased the area over which winter wheats may be grown.

The amount of rainfall has an important bearing on the depth of seeding. In sections where rainfall is heavy, most crops should be seeded comparatively shallow, as when seeds are sown deep in such sections the soil surrounding the seeds may remain saturated with water long enough to interfere with proper germination. In dry sections, however, it is necessary to place the seeds deep enough to bring them in contact with the soil moisture. The climate and season also have an important bearing on the rate of seeding. When fall-seeded grains are sown in sections where winters are severe, it is necessary to sow more seed to the acre than is the case where winters are mild. In the southern part of the winter wheat belt, 4 to 6 pecks of wheat to the acre give satisfactory results, while in the northern part of this belt 8 to 10 pecks to the acre are commonly sown. In like manner, 1 to 2 bushels of winter oats

to the acre give satisfactory results in the southern part of the winter oats belt, while in the northern part of this area 3 to 4 bushels must be sown to the acre for best results. In the milder sections tillering of the plants is more pronounced and the stand from thin seeding is thus thickened. In the colder sections winter-killing is common and enough seed must be sown to allow for partial winter-killing and still have enough plants left for a sufficient stand. Then too, when winter grains are seeded thickly the crowded plants serve as a protection for one another. In sections where the nature of the soil commonly causes crusting or baking of the land after heavy showers, it is often hard to secure good stands of such crops as soybeans and cowpeas. In these crops the cotyledons are pushed through the surface after germination has taken place, and if a crust has been formed on the surface many of them are broken off. Where such showers are common, these crops should be planted just deep enough to be thoroughly covered, and it is better to leave the seedbed loose on top rather than compact.

Relation of Seeding Practices to Time of Seeding.—The time of seeding has an important bearing on both the rate of seeding and the amount of fertilizer to use on winter wheat. When seeding has been delayed beyond the best seeding date for the section it is a common practice among farmers to sow an unusually large quantity of wheat to the acre. The wisdom of this practice is borne out by the work of Stephens and Hill (1917) in Oregon. These investigators found that heavy seedings were necessary in order to obtain a stand when seeding was delayed.

Ellett and Wolfe (1920) in Virginia have shown a strong relation between the kind of fertilizers used and the amount of winter-killing in wheat. These findings indicate that wheat on soils made productive by the use of liberal applications of the right kind of fertilizers withstands winter-killing much better than wheat on unproductive soil. This result is to be expected as wheat usually starts more rapidly on productive soils and acquires a better root system before severe weather sets in. This would suggest that it is very important to see that growing conditions are right when small grains subject to winter-killing are seeded late.

The method of seeding certain crops varies in certain sections according to the time of seeding. In the sections of the South where early potatoes are planted for the summer market, it is a common practice to ridge the land and plant potatoes on these ridges above the general level of the field. In this same section the late crop of potatoes is planted 3 to 6 inches below the level of the field. Where corn is planted very early in the season, while the ground is still cold and wet, it should be planted very shallow. Later plantings may be planted deeper. In cases where dry weather is likely to occur soon after planting, it may

be advisable to list the land or to open furrows 4 to 6 inches deep, plant the corn in the bottom of the furrows and cover 2 to 3 inches deep.

Relation of Soil Productivity to Rate of Planting.—As a rule, since tillering is greater on productive soils and since the increase in number of tillers makes up for the thinner seeding, small grains are seeded at a heavier rate on thin soils than on the more productive soils. Hickman (1901) in Ohio recommends 8 to 9 pecks of wheat per acre on the poor soils of Ohio and 5 to 6 pecks on the rich soils.

Hutcheson and Wolfe (1917*a*) in Virginia found that on soils capable of producing 15 to 25 bushels to the acre, seeding 6 pecks of wheat to the acre gave a larger yield than smaller quantities, while on soils capable of producing 20 to 35 bushels to the acre, 4 pecks of seed produced greater yields than either larger or smaller quantities.

In the case of inter-tilled crops such as corn, potatoes and tobacco the plants may be left thicker on rich soils than on poor soils. These crops do not tiller to any appreciable extent, and therefore must be planted at the rates that will utilize the plant nutrients of the soil most economically. Mooers (1920) found that in Tennessee, on soil with an expectancy of 20 or 25 bushels to the acre in a fair season, 3,000 stalks of corn to the acre gave highest yields, while on soil capable of producing 60 or 70 bushels per acre in a fair season, maximum yields were obtained from 7,000 stalks to the acre. Mooers also found that different varieties of corn require appreciably different rates of planting. In general, the small and short-season varieties required thicker planting than the larger, long-season varieties.

Relation of Soil Moisture to Method of Seeding.—Too much moisture in the soil usually retards germination and induces rotting of seed in the ground. Rice may be considered an exception. On the other hand, all seeds require moisture for germination and plants require water for growth. For this reason different methods of seeding are practiced in soils of different moisture conditions at planting time. In those sections of the country where rainfall is likely to be abundant at planting time, corn and other cultivated crops are planted just deep enough to insure germination. Usually the fields are made as level as practicable and the seed is placed just below the surface of the soil. In sections where soil moisture is likely to be low at planting time and during the early stages of growth, listing is often practiced, especially with corn. The term "listing" as used here should not be confused with the practice of throwing two furrows together and planting on the ridge so formed, sometimes called listing in parts of the South. Listing in the true sense consists in opening a furrow several inches deep by means of an implement with a double moldboard, and depositing the seed about 2 inches below the bottom of the furrow. This method of planting corn is in common use in semi-arid regions. The advantages of the practice are that the seed is

deposited in a moist area and that the roots of the corn, being deeper than those of surface-planted corn, suffer less from drought and heavy wind.

Where drainage is poor, crops are often planted on ridges or beds. These ridges may be wide enough for several rows or there may be a ridge for each row. When crops are planted on ridges, the seed is usually planted above the general level of the surface of the field and the furrows between the ridges act as drains; thus it is improbable that the area immediately around the seed will become saturated. This method is in common use on river bottoms subject to overflow and on other lands which are likely to be wet and cold during the early period of plant growth.

Relation of Topography and Weeds to Method of Planting.—Much has been written concerning the relative value of planting crops, particularly corn, in drills which allow for cultivation only one way, and in check rows which allow for cultivation both ways. The evidence on this point is somewhat conflicting but the difference in favor of one method over the other is usually not very great. The most commonly accepted belief is that yields will be practically equal under both methods if the fields are kept equally free of weeds and the same number of plants left to the acre. Where the topography of the fields is rolling and the land is subject to erosion, drill rows following the contour lines of the fields will be found more satisfactory. If crops are planted in check rows on rolling land, the cultivation up and down the hill will favor erosion. On comparatively level land there is no choice between the two methods unless weed pests are serious. In the case of very weedy land, checking usually pays, as it allows for cultivation both ways and facilitates weed destruction. Mooers (1920) in Tennessee has found that corn rows just wide enough for easy passage of cultivating implements with the required number of plants evenly distributed in the rows give better results than very wide rows with the plants thickly planted in the rows.

Relation of Seeding Practices to Crop Use.—In certain crops the use to which the crop is to be put governs the seeding practice. The soybean crop serves well to illustrate this point. If soybeans are grown for hay, they are commonly seeded thickly just as small grains are sown. If the crop is to be harvested for seed, it is usually desirable to seed in drills wide enough apart to admit of cultivation though the thick seeding method may be used. Kinney and Roberts (1921) in Kentucky have shown that practically the same yields of hay are obtained from soybeans seeded thickly as from those seeded in rows 20 inches apart. However, seed yields are slighly greater from soybeans seeded in rows rather far apart. Then too, the soybeans sown in rows have fewer weeds and are easier to harvest. Where the soybeans are threshed from the standing stalks in the field, they must be planted in rather wide rows to prevent injury during harvest. Only about half as much seed is required for

seeding in rows as is required for seeding thickly. However, the expense of cultivating the plants in wide rows will usually equal that of the extra seed required for sowing thickly; consequently, there is no economy in row seeding when soybeans are intended for hay. If soybeans are to be used with corn for silage or for hogging down, they may be planted in the same row with the corn. There are machines on the market which will plant the two crops in alternate hills and thus insure an even distribution of both crops.

Dates of Seeding.—The data shown in Table XXX, compiled by Covert (1910) and published in the Yearbook of the United States Depart-

TABLE XXX.—MEAN DATE FOR SOWING OR PLANTING SPECIFIED CROPS, WITH DISTINCTION OF BEGINNING, GENERAL AND ENDING, BY STATES

State	Spring sown barley			Corn			Flax		
	Beginning	General	Ending	Beginning	General	Ending	Beginning	General	Ending
Ala.	......	......	......	Mar. 12	Apr. 5	May 18			
Ark.	......	......	......	Mar. 18	Apr. 6	May 6			
Conn.	......	......	......	May 10	May 22	June 4			
Del.	......	......	......	Apr. 28	May 6	May 20			
Fla.	......	......	......	Feb. 21	Mar. 11	Apr. 2			
Ga.	......	......	......	Mar. 16	Apr. 4	May 7			
Ill.	......	......	......	Apr. 30	May 13	June 2			
Ind.	Mar. 27	Apr. 7	Apr. 19	May 1	May 14	May 31	Apr. 8	Apr. 28	May 9
Iowa	Apr. 8	Apr. 14	Apr. 22	May 4	May 13	May 26	May 1	May 17	June 6
Kan.	Mar. 18	Mar. 30	Apr. 13	Apr 14	Apr. 29	May 18	Apr. 5	Apr. 15	May 5
Ky.	......	......	......	Apr. 15	May 5	May 26			
La.	......	......	......	Feb. 27	Mar. 22	Apr. 24			
Maine	May 12	May 26	June 11	May 17	May 26	June 6			
Md.	......	......	......	Apr. 26	May 8	May 31			
Mass.	May 11	May 22	June 4	May 10	May 20	May 31			
Mich.	Apr. 25	May 4	May 15	May 15	May 22	June 2			
Minn.	May 1	May 10	May 20	May 13	May 19	May 30	May 9	May 20	June 2
Miss.	......	......	......	Mar. 12	Apr. 1	May 10			
Mo.	Mar. 15	Apr. 3	Apr. 15	Apr. 14	May 1	May 22	Apr. 7	Apr. 15	Apr. 25
Neb.	Apr. 8	Apr. 17	Apr. 28	May 3	May 13	May 29			
N. H.	May 16	May 21	June 4	May 14	May 24	June 4			
N. J.	......	......	......	May 6	May 14	May 31			
N. Y.	Apr. 23	Apr. 30	May 16	May 12	May 21	June 3			
N. C.	......	......	......	Mar. 30	Apr. 19	May 24			
N. D.	May 4	May 14	May 29	May 14	May 21	May 31	May 15	May 28	June 12
Ohio	Mar. 28	Apr. 8	Apr. 21	May 1	May 14	May 27			
Okla.	Feb. 26	Mar. 17	Mar. 31	Mar. 24	Apr. 7	Apr. 30			
Pa.	Apr. 8	Apr. 20	May 2	May 4	May 15	May 29			
R. I.	......	......	......	May 10	May 19	June 11			
S. C.	......	......	......	Mar. 18	Apr. 5	May 15			
S. D.	Apr. 14	Apr. 26	May 10	May 9	May 19	June 1	May 15	May 30	June 17
Tenn.	......	......	......	Mar. 31	Apr. 21	May 25			
Tex.	......	......	......	Feb. 27	Mar. 13	Apr. 4			
Vt.	May 12	May 22	June 8	May 17	May 25	June 4			
Va.	......	......	......	Apr. 20	May 2	May 21			
W. Va.	......	......	......	Apr. 26	May 10	May 27			
Wis.	Apr. 23	Apr. 30	May 9	May 11	May 18	May 28	May 5	May 14	May 26

Table XXX.—Mean Date for Sowing or Planting Specified Crops, with Distinction of Beginning, General and Ending, by States (*Continued*)

State	Cotton			Tobacco			Buckwheat		
	Beginning	General	Ending	Beginning	General	Ending	Beginning	General	Ending
Ala.	Apr. 8	Apr. 20	May 11						
Ark.	Apr. 15	Apr. 28	May 13	May 12	May 24	June 4			
Conn.	......	......	......	May 26	June 10	June 24			
Fla.	Mar. 16	Mar. 28	Apr. 20	Mar. 25	Apr. 20	May 15			
Ga.	Apr. 5	Apr. 21	May 12	Apr. 19	May 4	May 23			
Ill.	......	......	......	May 23	May 28	June 14	June 26	July 3	July 10
Ind.	......	......	......	May 25	June 9	June 26	June 17	June 26	July 3
Iowa	......	......	......	......	......	......	June 18	June 26	July 6
Ky.	......	......	......	May 18	June 1	June 17			
La.	Mar. 29	Apr. 15	May 7						
Me.	....	......	......	......	......	......	June 4	June 15	June 25
Md.	......	......	......	May 23	June 8	June 23	June 13	June 26	July 16
Mass.	......	......	......	May 28	June 12	June 26	June 20	June 27	July 5
Mich.	......	......	......	......	......	......	June 16	June 24	July 3
Minn.	......	......	......	......	......	......	June 6	June 17	June 24
Miss.	Apr. 5	Apr. 21	May 11						
Mo.	Apr. 25	May 4	May 14	May 27	June 7	June 20	June 28	July 9	July 27
Neb.	......	......	......	......	......	......	June 16	June 24	July 6
N. H.	......	......	......	......	......	......	May 27	June 6	June 18
N. J.	......	......	......	......	......	......	July 2	July 8	July 18
N. Y.	......	......	......	June 1	June 15	June 30	June 22	July 1	July 11
N. C.	Apr. 19	May 1	May 16	Apr. 29	May 14	May 31	June 25	July 4	July 15
Ohio	......	......	......	May 28	June 11	June 25	June 21	June 30	July 10
Okla.	Apr. 18	May 2	May 24						
Pa.	......	......	......	May 30	June 12	June 27	June 14	June 28	July 10
S. C.	Apr. 5	Apr. 22	May 12	Apr. 10	Apr. 23	May 3			
Tenn.	Apr. 21	May 2	May 16	May 10	May 22	June 5			
Tex.	Mar. 29	Apr. 13	May 9						
Vt.	......	......	......	......	......	......	June 12	June 20	June 28
Va.	......	......	......	May 16	June 5	June 20	May 28	June 14	July 8
W. Va.	......	......	......	May 23	June 5	June 22	June 14	June 27	July 9
Wis.	....	......	......	June 4	June 16	June 30	June 12	June 20	June 29

TABLE XXX.—MEAN DATE FOR SOWING OR PLANTING SPECIFIED CROPS, WITH DISTINCTION OF BEGINNING, GENERAL AND ENDING, BY STATES (*Continued*)

State	Fall sown oats			Spring wheat			Spring sown oats		
	Beginning	General	Ending	Beginning	General	Ending	Beginning	General	Ending
Ala.	Oct. 6	Oct. 24	Nov. 13	......	......	......	Jan. 31	Feb. 20	Mar. 9
Ark.	......	......	......	......	......	......	Feb. 15	Mar. 1	Mar. 18
Conn.	......	......	......	......	......	......	Apr. 9	Apr. 22	May 8
Fla.	Oct. 11	Nov. 6	Nov. 24						
Ga.	Oct. 2	Oct. 26	Nov. 19	......	......	......	Feb. 6	Feb. 27	Mar. 16
Ill.	......	......	......	Mar. 22	Apr. 1	Apr. 9	Mar. 19	Mar. 31	Apr. 14
Ind.	......	......	......	......	......	......	Mar. 20	Apr. 4	Apr. 18
Iowa	......	......	......	Mar. 29	Apr. 6	Apr. 14	Apr. 3	Apr. 11	Apr. 22
Kan.	......	......	......	Feb. 27	Mar. 13	Mar. 27	Mar. 7	Mar. 21	Apr. 3
Ky.	......	......	......	......	......	......	Mar. 8	Mar. 23	Apr. 11
La.	Oct. 16	Nov. 5	Nov. 22						
Me.	......	......	......	......	......	......	May 2	May 13	June 1
Md.	......	......	......	......	......	......	Mar. 20	Apr. 1	Apr. 21
Mass.	......	......	......	......	......	......	Apr. 10	Apr. 27	May 6
Mich.	......	......	......	Apr. 23	May 3	May 14	Apr. 20	Apr. 30	May 10
Minn.	......	......	......	Apr. 13	Apr. 23	May 5	Apr. 19	Apr. 29	May 9
Miss.	Oct. 3	Oct. 26	Oct. 31	......	......	......	Feb. 1	Feb. 19	Mar. 9
Mo.	......	......	......	......	......	......	Mar. 10	Mar. 25	Apr. 10
Neb.	......	......	......	Mar. 22	Apr. 2	Apr. 13	Apr. 2	Apr. 12	Apr. 23
N. H.	......	......	......	......	......	......	May 4	May 12	May 27
N. J.	......	......	......	......	......	......	Apr. 1	Apr. 12	Apr. 24
N. Y.	......	......	......	Apr. 14	Apr. 28	May 12	Apr. 19	Apr. 30	May 18
N. C.	Sept. 25	Oct. 14	Nov. 4	......	......	......	Feb. 21	Mar 7	Mar. 23
N. Dak.	......	......	......	Apr. 8	Apr. 21	May 9	Apr. 24	May 5	May 19
Ohio	......	......	......	......	......	......	Mar. 27	Apr. 9	Apr. 22
Okla.	......	......	......	......	......	......	Feb. 17	Mar. 4	Mar. 21
Pa.	......	......	......	Apr. 3	Apr. 17	May 2	Apr. 6	Apr. 19	May 2
R. I.	......	......	......	......	......	......	Apr. 13	Apr. 25	May 8
S. C.	Oct. 7	Oct. 31	Dec. 13	Jan. 29	Feb. 21	Mar. 12			
S. Dak.	......	......	......	Apr. 1	Apr. 14	Apr. 28	Apr. 8	Apr. 18	Apr. 30
Tenn.	......	......	......	......	......	......	Feb. 22	Mar. 11	Apr. 1
Tex.	Oct. 2	Oct. 24	Nov. 12	Jan. 25	Feb. 13	Feb. 23	Jan. 27	Feb. 10	Feb. 25
Vt.	......	......	......	Apr. 28	May 8	May 18	Apr. 29	May 9	May 22
Va.	......	......	......	......	......	......	Mar. 15	Mar. 28	Apr. 13
W. Va.	......	......	......	......	......	......	Mar. 26	Apr. 8	Apr. 22
Wis.	......	......	......	Apr. 10	Apr. 20	Apr. 27	Apr. 16	Apr. 24	May 7

TABLE XXX.—MEAN DATE FOR SOWING OR PLANTING SPECIFIED CROPS, WITH DISTINCTION OF BEGINNING, GENERAL AND ENDING, BY STATES (*Continued*)

State	Winter wheat			Winter rye			Fall sown barley		
	Beginning	General	Ending	Beginning	General	Ending	Beginning	General	Ending
Ala.	Oct. 4	Oct. 27	Nov. 22						
Ark.	Sept. 22	Oct. 11	Nov. 6						
Conn.	......	......	......	Sept. 6	Sept. 24	Oct. 16			
Del.	Oct. 3	Oct. 10	Oct. 26						
Ga.	Oct. 14	Nov. 5	Nov. 28	Sept. 17	Oct. 10	Nov. 10			
Ill.	Sept. 12	Sept. 24	Oct. 8	Sept. 5	Sept. 18	Oct. 5			
Ind.	Sept. 8	Sept. 21	Oct. 7	Sept. 2	Sept. 15	Oct. 2	Sept. 10	Sept. 22	Oct. 6
Iowa	Sept. 4	Sept. 15	Sept. 27	Sept. 7	Sept. 19	Oct. 3			
Kan.	Sept. 11	Sept. 26	Oct. 24	Sept. 2	Sept. 19	Oct. 4			
Ky.	Sept. 19	Oct. 5	Oct. 25	Sept. 6	Sept. 25	Oct. 19	Sept. 9	Sept. 27	Oct. 12
Md.	Sept. 18	Oct. 1	Oct. 20	Sept. 11	Sept. 25	Oct. 11			
Mass.	......	......	......	Aug. 28	Sept. 14	Oct. 4			
Mich.	Sept. 3	Sept. 14	Sept. 26	Sept. 6	Sept. 26	Oct. 9			
Minn.	Sept. 3	Sept. 12	Sept. 21	Sept. 3	Sept. 13	Sept. 25			
Mo.	Sept. 9	Sept. 23	Oct. 10	Sept. 3	Sept. 18	Oct. 6			
Neb.	Sept. 5	Sept. 17	Oct. 6	Sept. 7	Sept. 22	Oct. 2			
N. J.	Sept. 12	Sept. 24	Oct. 8	Sept. 9	Sept. 23	Oct. 14			
N. Y.	Sept. 4	Sept. 18	Oct. 2	Sept. 5	Sept. 19	Oct. 6			
N. C.	Oct. 14	Oct. 26	Nov. 15	Sept. 8	Sept. 30	Oct. 26			
Ohio	Sept. 11	Sept. 24	Oct. 10	Sept. 9	Sept. 22	Oct. 6	Sept. 8	Sept. 14	Sept. 24
Okla.	Sept. 13	Oct. 2	Oct. 29	Sept. 5	Sept. 22	Oct. 15			
Pa.	Sept. 2	Sept. 15	Oct. 4	Sept. 11	Sept. 24	Oct. 13			
R. I.	......	......	......	Sept. 6	Oct. 6	Oct. 25			
S. C.	Oct. 13	Nov. 5	Dec. 8	Sept. 22	Oct. 20	Nov. 27			
S. Dak.	Aug. 31	Sept. 16	Oct. 10	Sept. 6	Sept. 18	Sept. 30			
Tenn.	Sept. 22	Oct. 10	Nov. 14						
Tex.	Sept. 28	Oct. 20	Nov. 16	Sept. 16	Oct. 1	Oct. 24	Sept. 30	Oct. 20	Nov. 8
Vt.	Aug. 7	Aug. 27	Sept. 8	Aug. 25	Sept. 15	Oct. 10			
Va.	Sept. 20	Oct. 3	Oct. 21	Sept. 13	Oct. 2	Oct. 22			
W. Va.	Sept. 15	Sept. 28	Oct. 15	Sept. 13	Sept. 22	Oct. 15			
Wis.	Sept. 5	Sept. 14	Sept. 25	Sept. 11	Sept. 21	Oct. 2			

ment of Agriculture for 1910, give the most common dates for seeding eight of the important crops of the United States. Unfortunately, no data are available for several of the western states and many important crops are left out. However, the data for spring oats will serve as a guide for other early spring seeded crops and those for corn, cotton and tobacco for late spring and early summer seeded crops. Late summer seeded crops such as vetch, crimson clover, alfalfa and hay grasses give best results when seeded 30 to 40 days before the first killing frost date of the section. Early potatoes are usually planted 15 to 20 days before the last killing frost date in the spring so that the crop will come up very soon after danger of frost injury has passed.

Rates of Seeding.—In Table XXXI are given the usual rates for seeding a number of the common farm crops. These rates are not exact and will vary with the conditions. They, therefore, serve merely as suggestions.

Table XXXI.—Rate of Seeding per Acre of Important Field Crops

Corn for grain	8 to 12 lb.
Corn for silage	9 to 15 lb.
Wheat, winter	5 to 8 pk.
Wheat, spring	5 to 8 pk.
Oats, winter	2 to 4 bu.
Oats, spring	2 to 4 bu.
Rye	4 to 8 pk.
Barley	4 to 8 pk.
Potatoes	12 to 20 bu.
Soybeans seeded solid	4 to 10 pk.
Soybeans seeded in drills	1 to 4 pk.
Cowpeas seeded solid	4 to 8 pk.
Cowpeas seeded in drills	1 to 3 pk.
Rape broadcast	5 to 7 lb.
Rape in drills	3 to 5 lb.
Tobacco seedbed (plants for an acre)	¼ to ½ oz.
Tobacco plants	4,000 to 6,000 plants
Sweet potatoes seedbed	1 to 2 bbl.
Sweet potatoes plants	5,000 to 12,000 plants
Alfalfa	15 to 25 lb.
Clover, red	8 to 12 lb.
Clover, crimson	15 to 30 lb.
Clover, sweet hulled	15 to 25 lb.
Clover, sweet unhulled	20 to 30 lb.
Clover, white	4 to 6 lb.
Timothy	10 to 20 lb.
Orchard grass	14 to 28 lb.
Millet	20 to 50 lb.
Grain sorghums	4 to 6 lb.
Redtop	5 to 8 lb.
Vetch	40 to 60 lb.
Sorghum, for syrup	3 to 6 lb.
Sorghums, for forage	50 to 100 lb.
Peanuts	½ bu. shelled nuts

CHAPTER XV

TILLAGE

Tillage may be defined as the practice of working the soil for the purpose of bringing about more favorable conditions for plant growth. All operations that affect the soil, such as stirring, fining, firming and inverting, are included in tillage. The most common operations are plowing, harrowing, rolling and cultivating. The last operation will be discussed in this chapter.

Classes of Crops Based on Tillage.—Crops may be divided so far as tillage is concerned, into inter-tilled, and drilled or broadcasted. The former are sown or planted in rows at least far enough apart to allow cultivation to be readily practiced. In the inter-tilled class are found such crops as corn and sugar beets. The drilled or broadcasted crops are usually seeded broadcast, either by hand or by machinery. If crops are broadcasted by hand, the seeds are scattered indiscriminately over the land; but when seeded by machinery, they are placed in rows which are usually close together. Some commonly drilled or broadcasted crops are wheat, oats, rye and barley. The same crop may fall in either class according to the method of seeding. Such crops as soybeans and cowpeas are illustrations.

Development of Tillage Practices.—Jethro Tull is considered the father of modern tillage. In 1731 Tull published his book on "Horse-Hoeing Husbandry" in which was set forth a theory of tillage. According to Tull "tillage is manure" and the advantage resulting from cultivation was a freeing of the soil particles. He believed that earth was the only food for plants and that the plants fed from the minute particles of soil which were secured from around the soil grains; therefore, the more finely divided the soil, the better would the plant be nourished. It was believed that the chief benefit derived from the application of manure was that it pulverized the soil.

In the beginning of the nineteenth century the science of agricultural chemistry was developed through the work of Presitley, Liebig and others. At this time the conception of the nutrition of plants based on the assimilation of chemical elements from soil minerals, organic matter, water and air was evolved. With the development of this idea of nutrition of plants the reason given for tillage of the soil was that it increased the aëration and thereby increased the oxidation of chemical compounds in the soil and made them more available for plant use.

Gaylord (1841) stated that tillage was important in that it thoroughly stirred and mixed soil, and enabled the grower to change the relation of the soil in regard to moisture, temperature and plant nutrients. Goodale (1860) thought deep tillage and subsoiling were important in that roots were allowed to penetrate deeply in the soil for nutrients and water. Turner (1866) thought the real purpose of plowing was to put the soil into such a condition that the plant could more readily absorb energy, take up moisture and assimilate nourishment from the air and soil. According to Sweet (1871) the chief benefit to be derived from cultivation was the control of weeds. Johnson (1878) emphasized the importance of cultivation in loosening the soil, benefiting chemical reactions and improving moisture storage conditions and the structure of the soil. Davenport (1881) stated that cultivation is done primarily to pulverize and stir the surface of the soil, when it becomes hardened and baked by rains. As a result the soil is more retentive of moisture, and crops suffer less from drouth.

Effects of Tillage.—Crops are usually cultivated because cultivation increases the yields. The yields are increased on account of certain beneficial effects of the tillage operation on the soil and crop. Some of the ways in which cultivation of crops increases yields are as follows: (1) destruction of weeds, (2) conservation and storing of moisture and (3) aëration of the soil.

Killing of Weeds.—The destruction of weeds is usually the most important consideration in the cultivation of crops. Not only do weeds use plant nutrients and moisture that might otherwise be available to crops, but they may also cause injury to the crops by shading. Many experiments have been conducted which show the great benefit to be derived from cultivation through the destruction of weeds.

The results secured by Hutcheson, Hodgson and Wolfe (1917) in Virginia indicate that the greatest benefit to be derived from the cultivation of corn is that derived from killing the weeds. However, the results also strikingly show that cultivation is profitable even where there are no weeds.

When weeds were removed with a hoe, the soil not being stirred, there was, as compared with the plat receiving no cultivation, a 4-year average increased yield of 41 bushels of corn per acre. When three cultivations were given, the increase yield was 51 bushels; and when five cultivations were given, it was 50.5 bushels per acre. Therefore, cultivation increased the yield practically 10 bushels per acre over the plat where the weeds were removed with the hoe.

Mosier and Gustafson (1917) in Illinois found the 9-year average yield per acre of corn from the plat on which the weeds were removed with the hoe to be 48.9 bushels. When the weeds were allowed to grow, the yield was 7.5 bushels, or a difference of 41.4 bushels in favor of pre-

venting the growth of weeds. In order to determine whether weeds reduced the yield of corn by depriving the plants of moisture, one of the plats on which the weeds were allowed to grow was irrigated. The fact that the irrigated plat yielded only 2.5 bushels more to the acre than the non-irrigated plat, indicates that in this instance weeds did not materially reduce the yield of corn through the use of available moisture. However, irrigation increased the yields on cultivated plats.

Call and Sewell (1917) in Kansas found that weeds remove a large amount of water and nitrates from the soil. The results which they secured are given in Table XXXII.

Table XXXII.—Moisture and Nitrate Content of Plats Variously Treated

	Treatment			
	Weeds	3-in. mulch	6-in. mulch	Bare surface
Loss of moisture, May 29 to Sept. 23, 1916, in.	6.65	2.39	1.19	2.50
Gain or loss of NO_3 per acre upper 3 ft., Apr. 5 to Nov. 2, 1914, lb.	−121.51	483.94	369.26	620.26

Other results secured by these same investigators show that about as much nitrification takes place under weeds as under the mulched and bare-surface plats. Therefore, if the weeds are turned under the succeeding crop should receive as much nitrogen as that planted on the bare and mulched plats. The results in Table XXXII show the large amount of water and nitrogen used by weeds, which might otherwise be available to the crops.

Some experiments show that practically the only benefit to be derived from cultivation is the destruction of weeds. Other experiments, however, show that the cultivation of crops is also beneficial in other ways. Cates and Cox (1912) state that "cultivation is not beneficial to the corn plant except in so far as removing the weeds is concerned." However, the results of the experiments conducted by these investigators south of the latitude of Washington, D. C., show an increase in yield of 2.1 bushels of corn per acre from cultivation.

Numerous other experiments might be cited to show the injurious effect of weeds on crop production. The results discussed show clearly that weeds materially reduce the yields of crops.

Conservation and Storing of Moisture.—It is generally stated that cultivation conserves moisture by preventing evaporation from the surface of the soil and by enabling the plant to make more economical use

of water. Cultivation increases the moisture supply by reducing surface run-off and by killing weeds. There is at the present time much discussion as to the value of cultivation in the prevention of loss of water by surface evaporation. Some investigators state that cultivation is important from this standpoint, while others take the opposite view. It would seem, however, that cultivation should reduce loss by evaporation from the heavier types of soil, at least from those which are hard and baked on the surface and badly cracked.

Relation of Cultivation to Evaporation of Moisture.—Call and Sewell (1917) found in Kansas that cultivation did not reduce the loss of water from the soil by evaporation. On the other hand, Thom and Holtz (1914) in Washington found that land mulched 3 inches deep lost 0.55 inch of water, while land not cultivated lost 2.31 inches of water by evaporation. Knight (no date) at the Nevada Experiment Station found that land cultivated 6 inches deep lost 27.8 per cent less water by evaporation than uncultivated land.

Relation of Cultivation to Use of Water by Plants.—Plants growing on cultivated soil make more economical use of water than plants growing on uncultivated soil. In other words, plants that are cultivated use less water per unit of dry matter produced than plants not so treated. It is also well known that plants growing on rich soil make more economical use of water than plants produced on poor soils. Noyes (1922) states that cultivated plants require less water in the production of dry matter than uncultivated ones, as cultivation increases the available plant nutrients in the soil. Widtsoe (1909) of Utah states that "cultivation not only prevents direct evaporation of water from the soil, but also reduces materially the amount of water that must be transpired by a plant for the production of a certain definite quantity of dry matter."

Many crops require from 300 to 500 pounds of water to produce each pound of dry matter.

Relation of Cultivation to Loss of Water by Surface Run-off.—Cultivation helps to increase the supply of water by reducing surface run-off. The run-off is as a rule much greater from a smooth or uncultivated soil than from a rough or cultivated soil. Call and Sewell (1917) of Manhattan, Kansas, found some interesting facts in this regard. On the dry basis on disked plats, the average percentage of moisture in the soil from April 17 to September 9, 1916, was as follows: weeds growing, 16.72, per cent; mulched 3 inches, 19.59 per cent; mulched 6 inches, 17.92 per cent; and not mulched (bare surface), 17.81 per cent.

Aëration of the Soil.—It is usually necessary to have a well-aërated soil before the greatest and most favorable bacterial activities can take place. Air is also necessary for certain chemical and physical changes in the soil so important to plant growth in making plant nutrients more available and in improving the tilth of the soil. In addition to these

things air is usually necessary to the germination of seeds and growth of plants. However, this statement does not apply to such plants as rice. Cultivation stirs and turns the soil and in this way greatly increases the supply of air and keeps it agitated and well distributed.

Effect of Aëration on Availability of Plant Nutrients.—The effect of aëration on the production of available plant nutrients in the soil is very important. Oxygen and carbon dioxide are necessary for certain chemical changes in the soil that make the inert plant nutrients available. Numerous experiments may be cited to show that cultivation does not increase the supply of available plant nutrients in the soil through better aëration. Such results may be explained on the basis that the soil contained sufficient air to bring about the chemical and biological changes. If a sufficient amount of air is present in proportion to the other factors present for carrying on the processes, a further increase in the supply of air will not increase the amount of the product produced. Gainey and Metzler (1917) in Kansas found that nitrate accumulations were as great in a compact as in a loose soil, provided the moisture was not greater than two-thirds of saturation. This fact indicates that sufficient air for the nitrification process was present in the compact soil and that further aëration did not increase the amount of nitrate since oxygen was not limiting the production. Call and Sewell (1918) of Kansas state that cultivation does not cause an increase in the amount of nitrates accumulated, with the probable exception of heavy types of soil. These investigators present results as shown in Table XXXIII.

Table XXXIII.—Nitrates in Pounds per Acre as Influenced by Weeds and Cultivation, Kansas Experiment Station

Year	NO_3 in soil cultivated 3 in., lb.	NO_3 in soil with bare surface, lb.	NO_3 in soil producing weeds, lb.	Nitrogen in weed growth as NO_3, lb.	Total NO_3 developed in weeds and soil, lb.
1916	531.5	445.7	158.3	316.0	474.3
1917	372.0	361.2	36.5	322.3	358.8

Lyon and Buckman (1922, p. 256), citing the work of Stoklasa, show that there is some correlation between the amount of carbon dioxide in the soil air and the amount of P_2O_5 produced. The figures given are shown in Table XXXIV.

The results of experiments on the effect of cultivation on aëration indicate that on the heavier types of soil cultivation is beneficial in its effect on soil air, this being especially the case with soils which have a tendency to puddle and bake on the surface. However, in the more open types of soil, having only a slight tendency to bake and to form a

crust on the surface, the beneficial effect of cultivation on aëration of the soil is less marked.

TABLE XXXIV.—RELATION BETWEEN CARBON DIOXIDE CONTENT OF THE SOIL, AIR AND P_2O_5 PRODUCED

Kind of soil	P_2O_5 in drainage water (lb. to an acre)	Relative production of CO_2 (mg. to a lb. of soil in 24 hr.)
Loam	4.6	11
Clay	3.1	7
Lime	5.1	16
Organic	7.4	25

Tillage Practices with Inter-tilled Crops.—There is abundant proof that the cultivation of the crops ordinarily inter-tilled is very profitable. There is, however, much difference of opinion as to the number of cultivations necessary for most profitable returns, the depth of tillage most desirable and the best time at which the cultivations should be given. These things will vary with the kind of crop, the climate and the type of soil.

FIG. 13.—Cultivating corn with the one-row cultivator. (*U. S. Dept. Agr., States Relations Service*).

Frequency of Cultivations.—There is no reliable way of telling how frequently crops should be cultivated. The number of cultivations will vary with conditions. The results secured by Hutcheson, Hodgson and Wolfe (1917) in Virginia show that it is necessary to cultivate more frequently in dry than in wet seasons. At the Illinois Station, Mosier

and Gustafson (1915) found that corn cultivated shallow four or five times yielded 81.7 bushels, while that cultivated shallow twelve to fourteen times yielded 82.2 bushels, based on a 3-year average. The small increase secured from the large number of cultivations is not sufficient to pay for the extra labor involved.

Since the number of cultivations most advisable seems to depend upon several factors, no definite recommendation can be made in this regard. However, it may be said for those crops commonly inter-tilled that the cultivations should usually be frequent enough to keep down weeds and to keep a soil mulch over the surface of the field.

Depth of Cultivation.—For best results inter-tilled crops should practically always be given shallow cultivations. Cultivations which are too deep reduce the yield of crops. Shallow cultivation seems to be efficient in conserving water, aërating the soil and killing weeds.

Sanborn (1892) at the Utah Experiment Station reports a yield of 186.7 bushels of potatoes from no cultivation, 206.38 bushels from shallow cultivation and 204.87 bushels per acre from deep cultivation. At the Ohio Experiment Station, Williams (1903*a*) found the 9-year average yield of corn from deep cultivation, 4 inches, to be 56.4 bushels per acre. The yield from shallow cultivation, 1½ inches, was 60.4 bushels, a difference of 4 bushels in favor of shallow cultivation. Mosier and Gustafson (1915), in Illinois, report the results of root pruning and cultivation of corn as shown in Table XXXV.

TABLE XXXV.—RESULTS OF CULTIVATION OF CORN AND ROOT PRUNING (AVERAGE 3 YEARS)

Kind of cultivation	Yield, bu. per acre
None, weeds kept down by scraping with hoe	78.7
Shallow, 4 or 5 times	81.7
Deep, 4 or 5 times	73.3
Shallow, 12 or 14 times	82.2
Deep, 12 or 14 times	74.2
Root unpruned, shallow, ordinary	88.8
Roots pruned, shallow, ordinary	74.7
Roots unpruned, weeds scraped off with hoe	85.5
Roots puned with knife, weeds scraped off with hoe	71.8

Time of Cultivation.—If in the cultivation of crops the aim is to keep all weeds destroyed and to keep the surface of the ground mulched, it is necessary to cultivate the land as soon after each rain as practicable. The time of cultivation and the number of cultivations a crop should receive will vary largely with the season.

Mulches.—In the cultivation of crops a soil mulch is formed on the surface of the soil. The object of a mulch is to prevent the loss of water by evaporation. To be effective a mulch must be dry and reasonably fine. It is desirable to have a granular or soil mulch rather than a fine or dust mulch. The former breaks the capillary use of water more readily than the latter and is not so likely to form a crust after a shower.

Deep mulches are more effective in preventing loss by evaporation than are shallow mulches. However, the plant nutrients contained in the soil forming the mulch are not readily secured by plants. For this reason the land in which crops are growing should not be mulched too deep. As a general rule, land growing crops should be mulched about 2 inches deep.

The loss of water from soil mulched different depths is shown by Buckingham (1907) in Table XXXVI.

TABLE XXXVI.—EFFECT OF MULCHES OF DIFFERENT DEPTHS ON LOSS OF WATER, LEONARDTOWN LOAM

Depth of mulch, in.	Moisture lost per year, in.	Depth of mulch, in.	Moisture lost per year, in.
1	2.71	4	0.95
2	1.60	6	0.69

Kinds of Mulches.—Mulches are of two kinds, artificial and natural. All artificial mulches are formed by the application of some material, such as leaves, straw and manure, to the surface of the land. The use of such mulches is rather limited. The natural mulch is formed by stirring the surface of the soil and producing a loose, open condition. The latter kind of mulch is by far the most common and usually the most practical.

If a mulch is to be effective, it must be maintained. The difficulty in maintaining the natural or soil mulch depends largely on the type of soil. It is comparatively easy to maintain a mulch on soils that are high in organic matter and have a loose, open structure. The heavy soils which are low in organic matter and which have a tendency to run together and to become cloddy on wetting are difficult to keep properly mulched. However, on very sandy soils mulching is of little value.

CHAPTER XVI

HARVESTING AND STORAGE OF GRAIN CROPS

It is evidently important to harvest a crop at the time which will allow the greatest yield and at the same time insure a product of high quality. It is useless to go to the expense of producing a crop and to allow all or a part of it to waste because of untimely harvesting. Often inopportune harvesting cannot be avoided, but too frequently great neglect is shown at this stage of crop production. In case of a large acreage of the same crop and extremely favorable conditions for ripening, the crop frequently begins to deteriorate before harvesting is completed. On the other hand, crops are sometimes harvested before the optimum condition is reached. These two extremes should be avoided as far as practicable. Therefore, so far as the time of harvesting is concerned, losses may be due to harvesting too early or too late.

The problem of storage of grain crops, together with the factors affecting this problem, is also of great importance.

Losses from Delayed Harvesting.—In case of the small grains the chief causes of loss from harvesting crops too late are (1) shattering of the grain and (2) lodging or falling down of the plants.

With the corn crop the main loss is from the wasting and the deterioration of the blades. This loss is not always serious, as the stalks are sometimes left in the field after the ears have been pulled. In some sections this loss is more serious as the forage of the corn plant is an important source of feed for live stock and the leaves constitute the most nutritious part of the forage. However, about 85 per cent of the corn crop, including grain, is used for forage.

In the case of the small grains the loss from shattering varies with the variety, the number of times the unthreshed grain is handled, and the weather conditions. Some varieties of wheat retain the grain much better than others. The more often the unthreshed grain is handled, the greater the loss from shattering. Under continuous dry weather small grains are likely to shatter less than where dry and wet periods alternate.

The loss from lodging of grain crops from delayed harvesting is not so great as the loss which occurs when grain lodges before maturity. Lodged plants are more difficult to harvest and in many cases not all the grain can be obtained. Also, the damage from wet weather is usually greater in the case of lodged grain than in the case of that standing erect. The grain of lodged plants develops but little, if any, after lodging takes place.

Therefore, the loss is often severe when grain plants lodge early. This loss in development of the grain does not occur in the case of plants lodging from delayed harvesting.

In addition to the losses enumerated above, there is a loss due to the decrease in dry matter. This loss is a result of respiration in which certain gases are produced and lost. Kent, Patrick and others (1893) in Iowa found that the amount of dry matter in the kernel and in the cobs of ears of corn was as shown in Table XXXVII.

TABLE XXXVII.—AMOUNT OF DRY MATTER IN POUNDS IN THE KERNELS AND IN THE COBS OF EARS OF CORN ON 20 STALKS HARVESTED AT DIFFERENT DATES

Date of harvest	Total dry matter, lb.	
	Kernels	Cobs
Sept. 20	7.863	1.843
Sept. 27	8.816	1.703
Oct. 6	9.860	1.680
Oct. 12	9.719	1.686

The dry matter in the kernels increased until October 6, when there was a decrease. In the case of the cobs, the amount of dry matter was greatest at the earliest harvesting date.

Losses from Premature Harvesting.—The losses resulting from harvesting immature grain crops are shown by smaller yields and by reduction in quality. The small yields are due to failure of the grain to develop fully, and to shrinkage subsequent to harvesting. The weight of grain produced increases until maturity is reached. Thus, if the crop is cut much before maturity, a considerably smaller yield is likely to result. There is also a greater shrinkage loss from green grain than from that cut at the proper stage. This loss is often considerable in the case of grain harvested when very immature, as shown by the badly shriveled condition of the kernels.

Quality is often as important in grain production as is the quantity produced. The quality of immature grain is reduced by the extremely shriveled condition of the grain. In addition, green grain is more likely to be damaged by heating and molding both in the field and in storage than ripe grain.

Cardon (1915) found at Nephi, Utah, that wheat cut in the green dough stage yielded 4 bushels per acre less than wheat harvested in the hard dough stage. Kent, Patrick and others (1893) at the Iowa Experiment Station, found that the yield of ear corn harvested on September 20 was 12.7 per cent less than that harvested October 6, while that harvested

September 27 was 8.5 per cent less. On October 6 the crop was in proper stage for harvesting.

The Proper Stage for Harvesting.—A crop should be harvested at the time when the product will give the largest yield of the highest quality. The length of time during which a crop will remain just at the proper stage for harvesting varies with the season and kind of plant.

It can be readily realized that when a large acreage of a crop is grown, it is often not practicable to cut the entire crop at the ideal stage. The harvest often begins when the crop is somewhat green and is not finished until after the crop has matured. The object is to begin soon enough so as to harvest the largest part of the crop at the ideal stage. Thus, in the discussion of the proper stage for harvesting any particular crop, the difficulties due to acreage, weather and methods of harvesting must be kept in mind. It may often be impossible to cut the entire crop at the proper stage.

Corn.—The proper stage for cutting corn will vary, according to the uses to which the crop is to be put. The crop may be grown for the ears alone, for ears and stover or for silage. When the crop is grown for ears alone, not only are the plants allowed to become mature, but the ears are left on the stalk until ready for storage. It usually requires about a month for the ears to become ready for storage after the plant has matured or has been killed by frost. When the corn crop is to be harvested for both the ears and stover, it is desirable to allow the plant to become ripe; but harvesting should not be delayed too long, as the loss of leaves in cutting and shocking will be too great. By the time the crop is ready to be cut and shocked, the kernels are nearly all well glazed and, in dent corns, beginning to dent; the husks and the bottom leaves dry; and the upper leaves about one-fourth to one-half green. When ready to be cut for silage the corn crop has reached the early glazed stage, at which stage the husks begin to turn yellow. At this time the grain is in the late dough stage, which is attained about one week before the corn is ready to cut for grain and stover.

Yield of Corn at Different Stages of Development.—The yields of grain, stover, silage and dry matter of four different varieties of corn at different stages of development are reported by Hutcheson and Wolfe (1922) at the Virginia Experiment Station, as shown in Table XXXVIII.

Of these varieties, Boone County White and Leaming are grain varieties. The other two are strictly silage varieties. In the case of all varieties the yield of grain and dry matter increased as development progressed. The yield of silage seemed to be highest in the glazed stage.

Table XXXVIII.—Effect of Stage of Development on the Yield of Different Varieties of Corn in Virginia

Variety and date of planting	Stage of development	Yield per acre (4-yr. average)				
		Grain, bu.	Stover, tons	Silage, tons	Dry matter, lb.	
					Grain and stover	Silage (average 2 yr.)
May 3						
Boone Co. White...	Ripe........	58.59	1.90	10.97	5,540.43	6,425.18
Leaming...........	Ripe........	64.38	2.07	11.53	5,942.50	6,039.36
Cocke's Prolific....	Glazed......	48.90	4.08	16.67	7,843.87	8,259.46
Virginia Ensilage...	Glazed.....	49.65	4.56	15.81	6,104.28	7,190.47
May 10						
Boone Co. White...	Glazed......	59.89	3.00	13.66	5,680.57	6,830.55
Leaming...........	Glazed......	56.55	2.01	11.15	5,173.31	5,848.29
Cocke's Prolific....	Dough......	42.27	4.66	16.04	5,190.28	6,962.59
Virginia Ensilage...	Dough......	48.74	3.77	15.36	4,757.56	6,757.10
May 17						
Boone Co. White...	Dough.....	60.41	2.68	12.81	3,920.88	5,840.89
Leaming...........	Milk.......	47.88	1.81	9.42	3,411.73	5,026.34
Cocke's Prolific....	Dough.......	36.18	3.78	14.41	4,036.21	6,136.54
Virginia Ensilage...	Milk........	41.13	4.31	15.13	4,382.90	6,280.69
May 24						
Boone Co. White...	Milk........	45.14	2.51	11.82	2,921.43	5,110.12
Leaming...........	Milk........	43.84	2.35	10.59	4,064.04	5,568.44
Cocke's Prolific....	Grain forming	28.21	3.73	13.15	4,126.48	5,498.46
Virginia Ensilage...	Grain forming	29.98	4.01	13.39	4,141.42	5,799.69

Wheat.—The proper stage of development for harvesting wheat seems to be the dough stage. At that time the straw is beginning to turn yellow and the grain is soft enough to be readily dented by the thumb nail but not soft enough to be crushed between the fingers. There seems to be a continuous increase in yield until the grain reaches maturity. The most rapid increase apparently comes just before the dough stage; that is, when the grain can easily be crushed between the fingers. Therefore, wheat cut much before the dough stage will give a low yield of grain which will be shriveled, off color and of inferior quality. At the same time the crop should not be harvested too late, as the stalks are likely to lodge making harvesting more expensive and difficult and the loss from shattering

unduly great. When the binder is to be used the wheat harvest should be started so as to cut as much of the crop as possible in the dough stage. In case the header is to be used, the crop must be allowed to reach maturity. However, it has been found on the Pacific Coast that wheat cut with the binder has a higher percentage of protein, less yellow berry, than wheat cut later with headers.

The results secured by Cardon (1915) at Nephi, Utah, as to the proper stage of cutting wheat are shown in Table XXXIX.

TABLE XXXIX.—YIELD OF WHEAT HARVESTED AT VARIOUS STAGES OF GROWTH (4-YEAR AVERAGE)

Stage of development when harvested	Yield of grain, bu. per acre
Green dough	10.86
Hard dough	14.86
Fully ripe	14.06
Over-ripe	13.43

Latta (1894) from his results in Indiana states that wheat harvest should begin promptly when the wheat is in the dough stage and be completed by the time the grain is mature.

Oats.—When oats are grown for grain purposes, harvest should begin when the kernels are in the early dough stage and be completed before or by the time maturity is reached. At this time almost one-half of the leaves are green; and if the crop is shocked at once, the straw is comparatively palatable and nutritious. The results secured by Georgeson and others (1890) in Kansas show that the yield of oats from cutting in the dough stage was 32.6 bushels per acre; in the hard dough stage, 33 bushels; and in the mature stage, 33.2 bushels. If the crop is cut much before the early dough stage, it is difficult to cure and the yield is likely to be somewhat reduced. It is also important not to delay harvesting too long because of the danger of loss from shattering.

If the crop is to be cured for hay it should be cut when in the milk stage. According to the results secured in South Carolina by Keitt and Tarbox (1912), the highest percentages of protein and ash are obtained at this stage. The carbohydrates were higher at the beginning of the dough stage.

Barley and Rye.—Barley usually has a more mealy endosperm if cut when mature. If left standing too long, lodging and discoloration of the grain may result from exposure to the weather. Since color is so important in market grades of barley and since good quality is very important

for uniform germination, the crop is usually cut in the hard dough stage. At this time the straw is of a yellow color and of good quality.

Rye, like wheat, is usually cut when the grain is in the dough stage and is usually harvested one week before wheat.

Buckwheat.—This crop is usually harvested when the first seeds are mature. At this time seeds are to be found varying from the early milk stage to maturity. In cutting the crop, the object should be to secure the maximum yield of well-developed seeds. If the late seeds are allowed to mature, the early maturing seeds will have fallen from the plant. Thus, there will be some loss either from falling of the early maturing seeds or from lack of development of the late forming seeds.

HARVESTING METHODS FOR DIFFERENT GRAIN CROPS

Corn.—In the harvesting of the corn crop one of four methods is commonly followed; (1) The plant is harvested for fodder or silage; (2) the ears are harvested and the stalks left standing in the field; (3) the

FIG. 14.—*Harvesting corn with a binder. (U. S. Dept. Agr., States Relations Service).*

portion of the stalk above the ear is removed (topping) before the plant matures and the ear is left on the remainder of the stalk to ripen; (4) the leaves are removed from stalk while green (stripping). In addition to the above methods, the crop is sometimes harvested by a combination of topping and stripping.

Harvesting Corn for Fodder and Silage.—In the North Atlantic and southern states, and in central parts of the North Central states the

entire corn plant is harvested and shocked or put into the silo. Much of the cutting is done by hand, but in many cases corn harvesters and binders are used.

There are machines which cut and shock the crop in one operation but these are not generally used. Where the corn is cut for the silo, the corn binder is ordinarily used. When corn is cut and is later to be husked, it is placed in shocks of different sizes. The size of shocks usually varies from 35 hills to 144 hills per shock. The shocks may be built around a "saddle" made by tying the uncut stalks of 4 hills together. In other cases a wooden horse is used to support the shock until completed. After the shock has been completely built, the horse is removed and used for building the next shock. The shock is drawn tight with a rope and is tied either with twine or with stalks of corn. After the crop has cured, the time required for curing being about one month, the ears are usually husked by hand in the field and the stover is shocked in the field. The bundles of stover from four shocks of corn are usually placed together.

The crop after curing in the shock may be husked with the husker and shredder. In this method the labor of hand husking is avoided and the stover is cut into small pieces. The shredded stover is more easily handled than is the ordinary stover. It is necessary that the stover be dry when shredded to prevent molding in storage. However, the practice of shredding the corn crop has largely gone out of use.

The method of using the corn binder in harvesting corn for silage is more convenient and quicker than the other methods generally followed, although the difference in cost is slight.

Comparative Costs of Different Methods of Harvesting.—The cost of cutting and shocking an acre of corn by different methods as given by Zintheo (1907) is as follows: by hand, $1.50; with sled harvester, $1.18; with corn binder, $1.50; with corn shocker, $1.06. The cost of husking and shocking corn is given in Table XL.

Table XL.—Cost per Bushel of Picking and Husking Corn

	Cts.		Cts.
By hand from field	3.5	Additional cost of team for cribbing	0.79
Additional cost of team for cribbing	1.0	By corn picker from field	4.10
By hand from shock	5.3	By husker and shredder from shock	4.50

The cost of husking and preparing the fodder from an acre of corn is given in Table XLI.

TABLE XLI.—COST PER ACRE OF HUSKING CORN AND PREPARING FODDER

	By hand	Sled cutter	Binder	Shocker
Cutting and shocking corn	$1.50	$1.18	$1.50	$1.06
Husking out of shock by hand	2.68	2.68		
Husking and shredding by machine	.....	.....	4.41	4.41
Hauling and shredding fodder	2.50	2.50		
Comparative cost	$6.68	$6.36	$5.91	$5.47

Harvesting Ears.—In certain parts of the corn belt corn is "snapped," that is, the ears after becoming mature are pulled and cured and the stalks are left standing in the field. When this practice is followed, the stover is considered of little value; and when it is used, the live stock

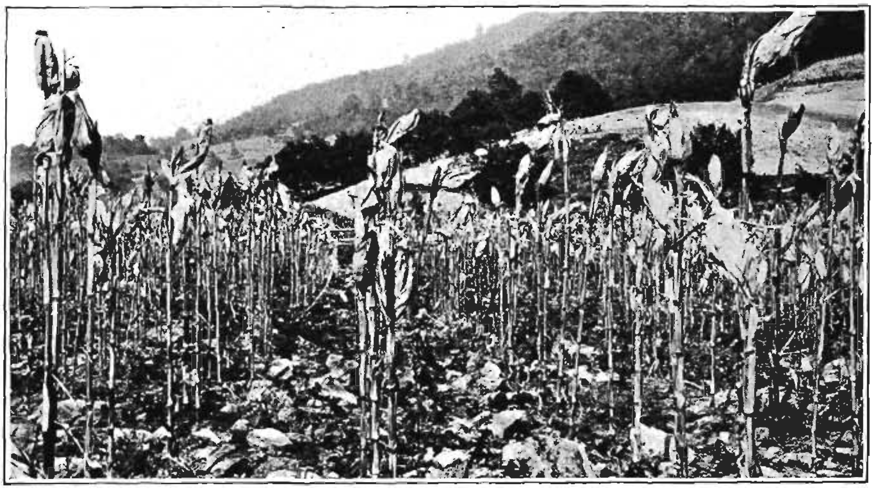

FIG. 15.—The corn crop topped and stripped. (*U. S. Dept. Agr., States Relations Service*).

are turned into the field. The net value per acre of the entire crop so harvested was $17.93 as compared with $23.18 where the crop was cut and the stalks were fed whole, and $24.68 where the crop was cut and the stalks were shredded (Zintheo, 1907). The ears may be removed either by hand or by machinery. The acre cost by the former method as given by Zintheo was $1.98, and by the latter $1.80.

Topping.—The practice of topping corn is often practiced in the North Atlantic and South Atlantic states. This method of harvesting is not to be advised generally as it frequently results in a decrease in yield of grain. Hunt (1891) at the Pennsylvania Experiment Station found that topping

reduced the size of the ears. As compared with the results from corn allowed to ripen on the stalk, topping produced 1,050 pounds of stover at at the loss of 540 pounds of ear corn. Tracy and Lloyd (1895) at the Mississippi Experiment Station found the 3-year average loss from topping to be more than 20 per cent. These investigators state that the average loss from topping at seven other experiment stations was 16 per cent. The feeding value in the tops is usually less than that lost by the decreased yield of grain.

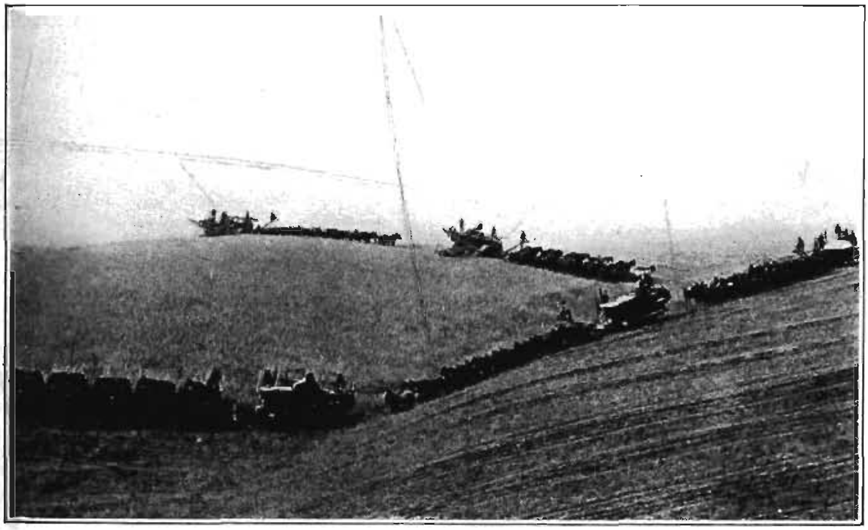

FIG. 16.—Combined harvesters at work in the Palouse country, Washington. (*U. S. Dept. Agr., States Relations Service*).

Stripping.—The method of harvesting corn by stripping off the leaves, commonly called "pulling fodder" is followed in some of the southern states. In some instances the leaves have a tendency to dry before the corn is mature. If pulled while still green, they make good forage. However, the practice of pulling leaves green enough to be palatable and nutritious decreases the yield of grain. The value of the leaves as feed is usually less than the value lost in the decreased yield of grain. The loss from this practice is in proportion to the state of greenness of the leaves when pulled.

Small Grains.—During the last 50 years the improvement in machinery for harvesting small grains such as wheat, oats, barley and rye has been very great. The earliest implement used was the sickle and this was followed in succession by the sycthe, the cradle, the self-rake reaper, the self-binding harvester, the header and the combined harvester and thresher. The rapid development of improved machinery for harvesting small grains has made possible the production of wheat and

other small grains on the extensive scale found in the West. On the large wheat farms of the West the header is sometimes used. On the Pacific Coast, because of the dry season during wheat harvest, the use of the combined harvester and thresher is possible. The machine most commonly used for harvesting small grain is the self-binding harvester. The cradle is seldom used except when it is impracticable to use a better machine. The self-rake reaper is sometimes used for cutting oats when they are somewhat green, soybeans for seed, buckwheat and so on. However, the use of this machine is now very limited in this country.

FIG. 17.—Harvesting wheat.

The common practice in harvesting small grains is to have laborers follow the reaper and place the bundles of grain in shocks for curing. The shocks usually contain 10 to 16 bundles, two of which are broken and serve as caps to protect the tops of the sheaves from the weather. In the case of oats and barley the shocks are built as for wheat but those of oats are usually somewhat smaller. Rye is shocked like wheat but sometimes no caps are used. The grain is usually left in the shock until cured, when it is threshed or stored to await threshing. The period required for curing depends largely on the ripeness of the grain when cut and on the weather conditions. However, the crop is usually ready to be removed from the field in about 10 days after cutting.

Buckwheat may be harvested with the self-binding harvester and shocked; each shock may contain 8 to 10 bundles without capping. Much of the crop is grown on mountain land and the crop is necessarily cut by the cradle, bound into bundles and shocked.

STORAGE

Shocks, Stacks, Ricks and Barns.—In harvesting most small grains they are placed in shocks to cure before being hauled from the field.

This is essential for the production and conservation of a product of high quality. However, on account of likelihood of damage from unfavorable weather conditions and destruction by birds, it is not advisable to leave the shocks in the field any longer than necessary for the curing process to be completed. In case of prolonged, damp weather the grain is likely to sprout or become lowered in quality because of molding and discoloration. Therefore, as soon as the grain and straw have sufficiently cured for storage in bulk, the crop should be taken from the shock and stored in larger bulk or threshed.

It is usually cheaper to thresh grain crops directly from the fields than to store and then thresh. The procedure to follow will depend upon the number of teams and laborers procurable, the weather and other conditions. More teams and laborers are required at one time to thresh directly from the field than to thresh from the bulk in storage. It is to be remembered that the grain may heat in storage if the threshing is done from the field. However, if the grain is spread in a thin layer 1 or 2 feet deep and stirred now and then, the damage is likely to be small. If the crop is kept in bulk for a while before threshing, the heating process takes place without any likelihood of damage. Thus, threshing before the grain goes through the heating process may result in low quality, because of lowered germination and bin burning.

When hauled from the field the small grain crops are usually stored in stacks, ricks or barns. The safest and most advisable place of storage is in covered sheds or barns for here the crop is protected from unfavorable weather conditions. It is more desirable to store the crop in ricks than in stacks. Stacks are usually built small and round and a comparatively high percentage of the crop is exposed to the weather. In certain sections of the country it is a common practice to store the unthreshed grain in small stacks; usually it would be a much better plan to store the crop in large ricks as is frequently done in the West.

Ordinarily the most practical way of handling the corn crop is to leave it shocked in the field until husked.

Bins.—The small grains and shelled corn are stored on the farm in bins. The things to be considered in storing are ease of handling, freedom from dampness and protection against insects and vermin. The bins should be built so as to secure these conditions as far as practicable. It is desirable to have the bins tight, deep in proportion to the other dimensions and rat-proof. A small exposure of surface area of grain lessens the chance of weevil and other infestations in storage. It is sometimes necessary to fumigate grains and in such cases tight receptacles will insure better results.

There is less loss to grain preserved in bins, which besides prevents any deterioration in quality. In California the wheat is often stored in

sacks piled out in the open field, a practice made possible by the dry climate.

Cribs.—Ear corn is commonly stored in slatted cribs or granaries. Storage houses of such a nature allow good ventilation and at the same time prevent material damage from weather. This method of storage is far superior to keeping the corn out in the open or in poorly ventilated houses. Ventilation is very important in the North, where corn is sometimes not mature when stored. The percentage of moisture often runs very high and if the crop does not dry out quickly, great damage from molding is likely to ensue. Hume and Center (1907) in Illinois found that ear corn lost in a period of 12 months from 12 to 20 per cent by shrinkage. Welton (1918) in Ohio found, as an average for 8 years, that well-matured corn placed in a box enclosed on two sides with wire netting lost 20.27 per cent in weight from November 1 to September 1. The loss for the same period of time based on a 5-year average for damp corn, the grain of which contained at the beginning 30.29 per cent moisture and the cobs 50.21 per cent, was 28.65 per cent. The loss was, therefore, 8.38 per cent greater in case of the damp corn. The importance of storing ear corn in well-ventilated places is evident. Welton (1918*a*) also shows the effect of storage conditions on germination of seed and subsequent yield of crop. The results are given in Table XLII.

TABLE XLII.—EFFECT OF STORAGE ON GERMINATION AND YIELD OF SEED CORN (5-YEAR AVERAGE)

Method of storage	Germination, per cent	Yield, bu. per acre	Germination, per cent 1918
In rack over crib	96.30	72.58	9.00
In pile on floor over crib	93.70	72.09	3.67
In rack over crib; ⅜ in. hole in cob	96.63	73.72	13.00
In box in crib	89.40	71.02	1.00
In rack in warm room	97.20	73.50	93.67
In wire box in warm room	95.67	74.07	94.33
In furnace room hung up	97.53	75.06	95.67
In bin of oats	92.83	71.20	85.83

These results indicate that seed corn should be stored in such a way as to protect the corn from freezing temperatures, or to allow it to become well cured before cold weather begins. The results of the germination test of 1918 are unusual, as the season of 1917 to 1918 was abnormal. Much immature corn was harvested in 1917, and badly damaged by freezing during the following winter.

Shrinkage in Grain.—It is important to know the amount of shrinkage likely to take place when grain is stored. This loss as well as

that from rats and mice should be taken into consideration when a farmer is deciding whether the crop can be more profitably sold at harvest or at some later date. The loss in shrinkage results from drying and by decrease of dry matter brought about by respiration and loss of certain gases, chiefly carbon dioxide.

Corn.—Duvel and Duval (1913) found the loss by shrinkage of shelled corn in transit to be greatest in grain having a high percentage of moisture. Corn having 19.8 per cent moisture when loaded had become hot, sour and discolored, and had lost 3.65 per cent by shrinkage in 27 days. Corn having 16.7 per cent moisture when loaded did not show any marked increase in temperature and had lost only 0.18 of 1 per cent by shrinkage in the 27 days. Ten Eyck and Shoesmith (1907*a*) found at the Kansas Experiment Station that of a total shrinkage of corn in storage of 14.48 per cent, only 6.91 per cent was due to loss of moisture. The loss in storage from shrinkage of grain as reported by Welton (1918) in Ohio is shown in Table XLIII.

TABLE XLIII.—SHRINKAGE IN EAR CORN IN STORAGE FROM NOVEMBER 1 TO

	Mature, 8-yr. average, per cent	Damp, 5-yr. average, per cent
Dec. 1	5.28	4.75
Jan. 1	7.03	7.90
Feb. 1	8.11	10.30
Mar. 1	9.42	12.45
Apr. 1	11.62	18.20
May 1	16.00	23.55
June 1	19.03	27.45
July 1	20.03	28.85
Aug. 1	20.41	29.20
Sept. 1	20.37	28.65
Oct. 1	19.18	28.15

The average percentage of moisture at the beginning in the shelled grain of the mature and damp corn was 24.91 per cent and 30.29 per cent, respectively; in the cobs it was 41.51 per cent and 50.21 per cent, respectively. In this experiment, 100 pounds of ear corn was placed in a wooden box, two sides of which were enclosed with wire netting, and placed in the loft of a corn crib.

In Kansas, Ten Eyck and Shoesmith (1907*a*) found the loss by shrinkage of ear corn 4 months after storage, in February, to be 3.26 per cent; in April, 5.16 per cent; in June, 6.8 per cent; in August 7.44 per cent; and in October, 12 months after cribbing, 8.62 per cent.

Small Grains.—The shrinkage of small grains in storage as reported by Welton (1918) from Ohio is shown in Table XLIV.

TABLE XLIV.—SHRINKAGE OF WHEAT, OATS AND RYE IN STORAGE

Date of experiment		Gain or loss, per cent		
Beginning	Ending	Wheat, 5-yr. av., per cent	Oats, 5-yr. av., per cent	Rye, 4-yr. av., per cent
Aug. 29, 1911	Oct. 23, 1912	−0.21	+0.55	
Sept. 3, 1912	Aug. 7, 1913	−0.71	−0.78	−1.92
Aug. 8, 1913	Aug. 10, 1914	+1.08	−1.72	+0.22
Aug. 10, 1914	Aug. 23, 1915	−0.21	+4.84	+1.21
Sept. 6, 1915	Sept. 2, 1916	−2.00	−2.03	−3.12
Average annual gain or loss		−0.41	+0.17	−0.90

The grains were stored in bins in a granary, 40 bushels of each being used.

Soybeans.—According to Welton the percentage of shrinkage of soybean seed, containing 17.67 per cent moisture at time of storage, was 3.76 per cent from November 2, 1911 to October 23, 1912.

Percentage of Moisture in Grains.—As shown by Welton (1918) in Ohio, the percentage of moisture in oats, wheat and rye does not vary much throughout the year.

TABLE XLV.—MOISTURE IN SMALL GRAINS

Date	Oats, 5-yr. av., per cent	Wheat, 5-yr. av., per cent	Rye, 4-yr. av., per cent
Sept. 1	12.84	13.53	14.68
Oct. 1	13.02	13.39	13.33
Nov. 1	12.54	13.65	13.94
Dec. 1	13.19	14.02	14.35
Jan. 1	13.45	13.79	13.96
Feb. 1	12.77	13.34	13.70
Mar. 1	12.97	13.85	14.06
Apr. 1	12.95	13.95	14.20
May 1	13.04	13.49	13.94
June 1	13.17	13.75	13.02
July 1	13.03	13.23	13.06
Aug. 1	12.67	13.34	13.24

The percentage of moisture in corn at various times of the year is reported by Williams and Welton (1915) from Ohio as given in Table XLVI.

TABLE XLVI.—MOISTURE CONTENT OF EAR CORN MONTH BY MONTH THROUGHOUT THE YEAR (6-YEAR AVERAGE)

Variety	Nov. 1, per cent	Dec. 1, per cent	Jan. 1, per cent	Feb. 1, per cent	Mar. 1, per cent	Apr. 1, per cent
Mid-season	24.29	20.34	19.73	19.49	18.46	15.45
Late	31.04	23.97	22.98	22.84	21.49	18.08

Variety	May 1, per cent	June 1, per cent	July 1, per cent	Aug. 1, per cent	Sept. 1, per cent	Oct. 1, per cent
Mid-season	13.09	11.49	10.24	10.08	10.81	11.13
Late	14.50	12.21	11.11	10.69	11.09	11.68

The results of this investigation indicate that the minimum amount of moisture in air-dried corn is around 10 per cent. Boerner (1919) states that thoroughly air-dried corn contains from about 12 to 13 per cent of moisture.

SOME INSECT PESTS

Angoumois Moth.—In stored grain the Angoumois grain moth or fly weevil (*Sitrotoga cerealella*) is very destructive. The adult is a moth measuring only about ½ inch across the expanded wings, light gray to buff in color, with a black spot about midway of each wing.

The adult deposits its eggs upon exposed grain either in the field or in storage. The eggs hatch in from 4 to 7 days and the larvae bore into the kernels and feed on the interior for about 3 weeks when they become full grown. The larvae pupate for from 6 to 10 days and then emerge as adults through cavities previously made by the larvae for this purpose. Several generations are produced each year. The insect overwinters in the larval stage inside of grain and in the early spring pupates and emerges as a moth about the time wheat begins to head. The injury to the grain is done by the larva which consumes the interior.

Control.—In control of the insect prompt harvesting and then storage under conditions unfavorable to the insect attacks are recommended. Kyle (1918) has shown that corn with long tight husks is less injured by

this insect than ears not well covered. In cases of infestation the insects may be destroyed by the use of 5 pounds of carbon bisulphide to each 100 bushels of grain or 1,000 cubic feet of space. The treatment must be given in tight bins or containers; and as the fumes are highly inflammable, all fire should be kept away. The liquid may be poured on top of the grain and the grain covered for 24 to 48 hours, when the cover may be removed to allow the grain to air.

CHAPTER XVII

HARVESTING FORAGE CROPS

According to Piper "forage crops properly include only those plants grown primarily for feed, and of which animals consume all or most of the harvested herbage or roots or both. A forage crop may be cut and preserved as hay, coarse fodder, or ensilage, or may be cut and fed green. Most cereal crops are also grown in some places for hay or silage, and when thus employed may be considered forage crops." The term "hay and forage" of the census is not strictly correct as hay is forage and, therefore, the phrase should read "hay, coarse fodder, and silage."

Losses from Delayed Harvesting.—The losses resulting from the delayed harvesting of forage crops are due largely to one or more of the following causes: (1) shattering of the leaves, (2) lodging, (3) reduction in palatability, (4) decrease in nutritive value and (5) lower yield of subsequent cuttings.

Shattering.—The loss from shattering is especially noticeable in the case of leguminous crops. When the harvesting of crops is delayed too long, there is a great tendency for the leaves to dry and fall to the ground or to break off in handling. According to Cooke (1900), in Colorado the mechanical loss from handling alfalfa under ordinary farm conditions varies from 5 to 10 per cent. The fallen leaves cannot be saved for feed and from that standpoint are lost; but as they enrich the soil to some extent, they cannot be regarded as a total loss. The leaves of legumes are usually very high in feeding value as compared with the other vegetative parts of the plant. Swanson (1916) of Kansas states that the leaves of alfalfa as compared with the stems contain a higher percentage of ash, nitrogen-free extract, ether extract, and more than twice as much protein. The leaves of the alfalfa plant constitute about 50 per cent of the forage, but over 70 per cent of the total protein is contained in them. It is important, therefore, to prevent the loss of leaves as far as practicable.

According to Montgomery (1915, page 403), red clover plants are made up of 60 per cent stem, 30 per cent leaves and 10 per cent flower heads. The percentage of protein in the different parts is as follows: stem 8.6 per cent, leaf stalks 11.2 per cent, flower heads 18.2 per cent and leaves 24.6 per cent. It is important in harvesting forage crops to save as many leaves as possible.

Lodging.—Plants growing in rich land often have a tendency to lodge, especially in seasons of much rainfall. After the crop has fallen to the

ground it is difficult to cut with the mower and much is left on the ground. In addition to the loss due to failure to secure all of the crop, the products obtained are often damaged because of contact with moist or wet ground. Growing plants have a tendency to become erect after lodging. However, in the case of fully developed plants this tendency to straighten is often not pronounced. Some of the forage plants have a more marked tendency to lodge than others, and this fact is strikingly true of alsike clover and mammoth clover as compared with red clover.

Reduction in Palatability.—As a rule the palatability of forage crops decreases with the increase in development. This is at least true after the plants have passed the best stage of development so far as the production of the maximum amount of digestible nutrients is concerned. With full development is usually found a woody condition of the stems and a relatively high percentage of crude fiber. Hunt (1889) in Illinois found the crude fiber content of orchard grass in bloom to be 34.13 per cent and when in seed, 35.63 per cent. After orchard grass has passed the full-bloom stage, the crop becomes woody, less palatable and less digestible. Iversen and Kristensen (1917) in Denmark found that orchard grass changed in chemical composition with increase in development and that the digestibility and feeding value were diminished to a considerable extent.

Waters (1915) at the Missouri Experiment Station studied the palatability of timothy hay cut when just coming into bloom, when in full bloom, when the seeds had just been formed, when the seeds were in dough and when the seeds were ripe. The experiments showed that milk cows fed on grain and silage evidenced a decided preference for the early cuttings. Steers fed on timothy hay alone showed a preference for the earlier cuttings but not so decided a preference as was shown by the cows. Fall-fed sheep showed no choice between the different cuttings. The results clearly indicate that the earliest cut hay was the most palatable and decreased in palatability with increase in the stage of development. Foster and Merrill (1899) in Utah found early-cut alfalfa to be slightly more palatable than the crop cut in the late stage of maturity.

Decrease in Nutritive Value.—There is generally a decrease in digestibility and feeding value of forage crops when the stage of maturity is reached. This has been shown to be true in the case of orchard grass.

Waters (1915) gives the data as presented in Table XLVII in regard to the composition of timothy cut at various stages of growth.

In regard to digestibility of the nutrients the results show that the optimum yields of digestible dry matter, digestible protein, digestible crude fiber, digestible ash and digestible nitrogen-free extract were reached when the plants were in full bloom. When the seeds were ripe as compared with the stage of full bloom, the digestible dry matter was only eight-tenths as much. This stage showed less than two-thirds as

much digestible protein, approximately eight-tenths as much digestible nitrogen-free extract and less than nine-tenths as much digestible fiber.

TABLE XLVII.—AVERAGE PERCENTAGE COMPOSITION OF TIMOTHY HAY, ON WATER-FREE BASIS

Stage of cutting and averages	Crude protein, per cent	Ether extract, per cent	Crude fiber, per cent	Ash, per cent	Nitrogen-free extract, per cent
Just coming into bloom, 3 yr.	7.74	3.34	34.37	6.57	47.99
In full bloom, 4 yr.	7.07	3.15	33.42	6.11	50.26
Seed just formed, 5 yr.	6.41	2.76	35.96	5.24	49.56
Seed in dough, 5 yr.	5.95	2.92	35.49	4.86	50.79
Seed fully ripe, 5 yr.	5.82	2.79	34.87	5.53	51.00

Hunt (1889) in Illinois found that mammoth red clover yielded less digestible dry matter, crude protein, crude fat, crude fiber and nitrogen-free extract when the plants were nearly out of bloom than when in full bloom. The data of three different stages are given in Table XLVIII.

TABLE XLVIII.—YIELD PER ACRE OF DIGESTIBLE CONSTITUENTS OF MAMMOTH RED CLOVER HAY CUT AT DIFFERENT STAGES OF GROWTH

Stage of cutting	Organic substance, lb.	Crude protein, lb.	Crude fat, lb.	Crude fiber, lb.	Nitrogen-free extract, lb.
Beginning to bloom	2,036	328	150	544	1,014
Full bloom	2,299	348	149	674	1,128
Nearly out of bloom	1,806	227	78	433	1,068

Ladd and Shepperd (1901) in North Dakota found that the valuable food constituents of *Bromus inermis* hay increased until full development was reached. This result contrasts with those secured with timothy hay by Waters (1915).

Swanson (1916) states that early-cut alfalfa in Kansas has a larger number of pounds of protein and ash per ton than late-cut alfalfa. However, the reverse is true in regard to crude fiber and nitrogen free extract. A ton of alfalfa cut in one-tenth bloom produced 68 pounds more protein than a ton cut at the time of seed formation. The results shown in Table XLIX are reported on the basis of hay containing 10 per cent moisture.

TABLE XLIX.—POUNDS OF FEEDING CONSTITUENTS IN A TON OF ALFALFA CUT AT DIFFERENT STAGES OF GROWTH

Stage of growth	Ash, lb.	Crude protein, lb.	Crude fiber, lb.	Nitrogen-free extract, lb.	Ether extract, lb.
Cut in bud	212.4	393.0	450.0	701.2	47.2
Cut in one-tenth bloom	191.8	367.6	471.6	708.4	58.6
Cut in full bloom	175.8	326.0	500.2	721.4	75.4
Cut in seed	150.6	299.6	530.4	747.2	66.8

Foster and Merrill (1899) in Utan found that alfalfa cut in the late-bloom stage produced less digestible matter and a smaller yield of hay and gave less gain in weight when fed than alfalfa cut in early bloom.

TABLE L.—EFFECT OF STAGE OF CUTTING ALFALFA ON YIELD OF HAY AND DIGESTIBLE MATTER AND GAIN OF BEEF AT THE UTAH EXPERIMENT STATION (AVERAGE OF 5 YEARS)

Stage of development	Hay, lb. per acre	Digestible matter, lb. per acre	Beef products, lb.
One-tenth bloom	10,719	6,413	705.61
Full bloom	9,829	5,912	561.88
One-half bloom	9,100	5,309	490.50

When forage crops approach maturity a loss in dry matter is often apparent. This loss may result from shattering of leaves and finer parts of the stems; from respiration; from translocation of material to the bulbs in plants like timothy, and to the seeds in plants like wheat, oats and corn; and from loss by solvent action of rain. This latter loss has been shown to be greater when the crop is mature than when immature.

Lower Yields of Subsequent Cuttings.—The effect of the time of cutting forage crops is not only important from the standpoint of the immediate crop, but in the consideration of the subsequent cuttings. In some cases it seems that allowing a crop to become fully developed does not reduce the yield of the subsequent cutting, but actually increases it. On the other hand, in some instances when the crop is allowed to mature, the yield of the subsequent cutting is smaller than if the preceding crop had been cut at a stage before maturity.

Losses from Premature Harvesting.—Under normal conditions it is poor economy to harvest forage crops too soon. The disadvantages

likely to occur are: (1) lower yields of food constituents, (2) lower yields of dry matter and (3) greater difficulty in curing.

Lower Yield of Food Constituents.—The results of Trowbridge, Haigh and Moulton (1915) in Missouri show the change in yield of different nutrients in the timothy plant, according to the stage of growth.

TABLE LI.—EFFECTS OF STAGE OF DEVELOPMENT ON CHEMICAL ANALYSIS OF TIMOTHY HAY, POUNDS PER ACRE

Stage of development	Dry matter, lb.	Protein, lb.	Fat, lb.	Crude fiber, lb.	Ash, lb.	Nitrogen-free extract, lb.
About 1 ft. high, no heads showing	1,472.1	149.7	67.9	387.4	123.8	743.2
Beginning to head	2,093.9	167.9	85.3	652.3	159.4	1,029.0
In full bloom	3,287.5	196.2	78.6	1,107.6	200.3	1,704.9
Just out of bloom and seed formed	3,975.8	213.2	123.7	1,268.1	221.3	2,149.6
Seed all in dough	4,508.8	231.5	129.2	1,356.2	243.0	2,548.9
Seed fully ripe	4,114.8	213.9	112.9	1,270.7	215.1	2,302.2

The results show that if timothy hay is cut too soon, the yields of dry matter and food constituents are lower than those of hay cut in a later stage of development. The percentages of protein, fat and ash are higher in the earlier stages, but the total production of these constituents is lower owing to a smaller production of dry matter at this time.

Hunt (1889) in Illinois found that mammoth clover when beginning to bloom as compared with that in full bloom produced less organic matter, crude protein, crude fiber and nitrogen-free extract, but practically the same amount of crude fat. Meadow fescue in full bloom yielded less of all of these constituents than in the passed-bloom stage of development. This same condition also held for orchard grass when the full-bloom stage was compared with hay cut when the seeds were in the milk stage. Harcourt (1898) in Ontario found that alfalfa cut when the blossoms were one-third out yielded a larger amount of digestible matter than when the crop was harvested earlier or later.

As a rule there is a higher percentage of protein, ash and fat in the early cuttings of forage crops and the percentage of digestibility is also higher, as compared with cuttings made in later stages. The percentages of crude fiber and nitrogen-free extract are usually higher in the late cuttings. However, it is usually found that forage crops cut early in the stage of development produce a smaller yield per acre of digestible food constituents than those harvested at the proper stage.

Lower Yield of Dry Matter.—The yield of dry matter usually increases until full development is reached and then a decrease occurs. Trowbridge, Haigh and Moulton (1915) in Missouri found the dry matter of timothy hay to increase from early development until the seeds were in the dough stage. After the dough stage was reached, there was a decrease in the yield of dry matter.

Hunt (1889) in Illinois found that the yield per acre of digestible dry matter of timothy increased from the stage of full bloom until the seeds were nearly ripe. In case of orchard grass the digestible dry matter increased from full bloom to the time the seeds were in milk. The digestible dry matter of meadow fescue also increased with development. However, with red clover the digestible dry matter decreased from the time the heads were in bloom until the heads were all dead. There was more digestible dry matter produced by mammoth clover when in the full-bloom stage than either before or afterwards.

Greater Difficulty in Curing.—Forage crops cut in the early stage of development contain a higher percentage of water than those cut in the later stages. For this reason a longer time is required for curing. Often in the early part of the season the weather conditions are not so favorable as later and the ground may contain more moisture. These conditions, when they exist, make hay curing more hazardous. For the reasons just enumerated it is often more convenient to harvest forage crops rather late, although the earlier cuttings may be more palatable, and result in more completely digestible hay.

THE PROPER STAGE FOR HARVESTING SOME OF THE PRINCIPAL FORAGE CROPS

Grasses.—*Timothy* is the main grass plant cut for hay in the United States. According to Waters (1915) in Missouri, the crop should be harvested when in the stage of full bloom as at this time the highest yield of digestible nutrients is produced. The highest yield of hay was secured when the plants had formed seed.

Orchard grass should usually be cut when in full bloom. If left longer than this stage, the stems become woody and the crop becomes low in digestibility. Iversen and Kristensen (1917) in Denmark harvested orchard grass when just headed, when in full bloom, and when blooming was completed. The last cutting yielded only 1 hundredweight more per 1.36 acres than did the preceding cutting. The last cutting had decreased in digestibility and feeding value as compared with the earlier cuttings. If the crop is cut at the proper stage and if the weather and soil conditions are favorable, a good second crop will be secured. The second crop is seldom as large as the first.

Tall meadow oat grass, like orchard grass, should be cut when in bloom. After this stage of growth the stems become woody and the crop decreases in digestibility and feeding value. It is important to cut the crop when in the proper stage, not only from a feeding standpoint but also from the standpoint of the subsequent cuttings. On rich soil under favorable climatic conditions three or four cuttings can be secured each year. If the crop is cut at the proper stage, the subsequent cuttings will in all probability be larger.

Redtop is seldom seeded alone, but is commonly included in mixtures, especially with timothy. The time of maturity of the associated plants will largely govern the time the redtop will be cut. As a rule the associated plants are more important than the redtop. However, redtop, when seeded alone, should be cut when in full bloom; if left later than this stage, it will become dry, comparatively indigestible and lower in feeding value.

Bermuda grass and Johnson grass furnish much of the hay produced by permanent grasses in the southern states. Several cuttings each year can be obtained from these grasses. They should be cut when in full bloom, as at this time a larger amount of digestible nutrients per acre will be secured and the succeeding crops will be larger than when cut at a later stage of development.

Millet should be cut for hay when just passed the bloom stage. This is especially true if the crop is to be fed to horses. Millet is dangerous when fed in too large quantities to horses but cutting in the early stages lessens the danger and makes the crop more palatable. If the crop is to be fed to cattle or sheep, it may be left until the late milk stage is reached and fed without danger. However, when the crop is cut in the later stages the digestibility is lowered somewhat but the yield of hay is larger.

Legumes.—*Alfalfa* blooms more profusely in the drier sections of the country than in the humid sections. Where the crop blooms freely, the time of cutting is determined by the amount of the bloom present. Under such circumstances the best time to cut, from the standpoint of securing the largest amount of digestible nutrients, is shortly after the first blooms appear. In the humid regions the proper time of cutting is best determined from the length of the shoots which develop from the crowns. The crop should be cut when the shoots are from 1 to 1½ inches high. If the crop is cut at the proper stage a larger yield will be secured in the succeeding cutting than when the crop is harvested either earlier or later.

The experiments in Utah, according to Foster and Merrill (1899), show that the highest yield per acre of both hay and digestible matter in alfalfa is found when the first blooms appear. There were decreases in both hay and digestible matter in the later cuttings. The percentage of ash,

protein, fat and nitrogen-free extract decreased with maturity, while the percentage of fiber increased.

At the Kansas Experiment Station, Ten Eyck (1908*a*) found that the yield of alfalfa increased as the stage of development progressed. The crop was cut when in first bloom, one-tenth bloom, one-half bloom and full bloom. The respective yields per acre for the first cutting were 1.36, 1.76, 1.81 and 2.04 tons, and for the entire season, 4.69, 5.35, 4.52 and 5.99 tons. Willard (1908), also at the Kansas Experiment Station, found the percentage of ash, protein and fat to decrease with development while percentage of fiber and nitrogen-free extract increased.

TABLE LII.—PERCENTAGE COMPOSITION OF ALFALFA HAY CALCULATED TO THE WATER-FREE BASIS, KANSAS EXPERIMENT STATION

Stage of development	Ash, per cent	Crude protein, per cent	Pure protein, per cent	Crude fiber, per cent	Nitrogen free-extract, per cent	Crude fat, per cent
One-tenth bloom	10.45	18.50	14.86	32.20	27.29	1.56
One-half bloom	10.28	17.21	14.18	35.37	34.00	1.05
Full bloom	8.45	14.43	11.58	36.10	39.62	1.41

When in full bloom *red clover* seems to be at the proper stage for cutting. At this stage the largest yields of both hay and digestible nutrients are secured. Hunt (1889) in Illinois gives the yields of red clover cut in different stages of development as shown in Table LIII.

TABLE LIII.—RELATION BETWEEN STAGE OF DEVELOPMENT AND ACRE YIELDS OF RED CLOVER IN POUNDS (WATER-FREE BASIS)

Stage of development	Ill., lb.	Pa., lb.	Conn., lb.
Just before bloom	.....	.....	1,385
Full bloom	2,526	3,680	1,401
Some heads dead	.....	3,428	
Three-fourths heads dead	2,427		
All heads dead	.....	3,361	
Nearly out of bloom	.....	.....	1,750
Nearly ripe	.....	.....	1,523

The amount of food constituents in red clover at the different stages of development is given in Table LIV.

TABLE LIV.—RELATION BETWEEN STAGE OF DEVELOPMENT AND CHEMICAL ANALYSIS OF RED CLOVER HAY, POUNDS PER ACRE

Food constituents	Stage of development and state, lb.								
	Just before bloom, Conn.	Full bloom			Some heads dead, Pa.	¾ heads dead, Ill.	All heads dead, Pa.	Nearly out of bloom, Conn	Nearly ripe, Conn.
		Ill.	Pa.	Conn.					
Crude protein	198	400	539.5	189	469.3	379	420.7	230	158
Crude fat	24	197	116.3	33	105.6	156	93.7	31	36
Crude fiber	384	660	1,032.6	390	1,247.8	672	1,260.3	523	484
Nitrogen-free extract	664	1,052	1,731.4	682	1,379.1	1,024	1,378.3	837	746
Crude ash	115	217	260.2	107	226.2	196	208.0	129	99

Since the main stems continue to grow with the production of new parts *alsike clover* remains in the proper stage for cutting over a longer

FIG. 18.—Harvesting alsike clover in full bloom, the ideal stage for cutting clover hay.

period than red clover. The crop should usually be cut when in full bloom. As with red clover, under favorable conditions a second crop is obtained. The yield of the second crop is reduced if the harvest of the first is delayed too long.

Japan clover, or lespedeza, if harvested for hay, should be cut when the plants are full grown but before the leaves have begun to shed. At

this time part of the seeds will be ripe, but the plants will still be flowering near the top.

Hutchinson (1895) at the Mississippi Experiment Station gives the composition of Japan clover as shown in Table LV.

TABLE LV.—RELATION OF STAGE OF DEVELOPMENT OF JAPAN CLOVER TO PERCENTAGE OF COMPOSITION

Time of cutting	Crude fiber, per cent	Crude protein, per cent	Ether extract, per cent	Nitrogen-free extract, per cent	Ash, per cent
April	35.39	11.54	1.84	46.90	4.33
July	26.59	12.98	3.64	44.32	12.47
August, 20 in. high and blooming	30.26	13.44	4.57	45.75	5.98
August, 12 in. high and fruiting	32.34	14.40	4.33	42.87	6.06

Sweet clover for hay purposes should be cut as the first blooms appear. If harvested later than this stage, there is likely to be a large amount of woody material, and the yield of the subsequent cutting will be reduced. Fulmer (1916) in Ontario found that the percentages of ash, protein and fat decreased as development progressed, while there was an increase in the percentage of crude fiber. There seems to be but little effect of development on the percentage of soluble carbohydrates. On the other hand, development produced an increase in yield of air-dry hay, protein, fats, soluble carbohydrates, fiber, ash and digestible protein.

Cowpeas are important as a forage crop in the southern states. They should not be cut for hay until the first pods are ripe. The plants have an indeterminate habit of growth and for this reason the harvesting period may extend over a long period of time. If the crop is cut too green, it is difficult to cure, while delaying the harvest too long will result in loss of some of the early-maturing leaves. Harvesting can be delayed, however, without serious loss until many of the pods are ripe. Teller (1893) at the Arkansas Experiment Station found that the largest yields of hay were obtained when the majority of the pods were formed but not ripe. The data presented in Table LVII were secured in Arkansas from cowpeas planted June 13.

TABLE LVI.—THE TOTAL WEIGHT OF NUTRIENTS AND THE AMOUNT OF DIGESTIBLE PROTEIN FURNISHED BY 1 ACRE OF SWEET CLOVER AT 6 DIFFERENT STAGES OF DEVELOPMENT IN ONTARIO, CANADA

Date of cutting	Stage of maturity	Green weight, lb. per acre	Air-dry weight, lb. per acre	Lb. per acre of					Digestible protein, lb. per acre
				Protein	Fat	Soluble carbo-hydrates	Fiber	Ash	
June 5	Just before flower buds had formed	16,940	2,816	548	87.6	1,107	624	262	473
June 11	Flower buds formed	12,100	3,297	534	105.5	1,308	795	298	447
June 18	First bloom appearing	7,865	3,547	532	95.4	1,461	899	297	440
June 25	One-half in bloom	11,610	3,654	544	108.2	1,296	1,102	303	452
July 7	Full bloom	17,550	5,078	727	149.0	1,803	1,686	361	588
July 30	Seed filled and beginning to ripen	13,920	7,763	1,136	184.0	2,798	2,749	395	931

TABLE LVII.—CHEMICAL ANALYSIS OF AIR-DRY MATTER OF COWPEAS, VINES AND PEAS, IN POUNDS PER ACRE

	Aug. 7, lb.	Aug. 14, lb.	Aug. 20, lb.	Aug. 26, lb.	Sept. 2, lb.	Sept. 8, lb.	Sept. 14, lb.
Water	193.7	231.6	263.0	315.2	340.9	349.0	308.0
Ash	188.9	210.8	230.4	209.5	181.7	180.8	135.1
Crude protein	302.3	330.6	382.9	424.7	407.4	414.2	386.3
Ether extract	38.1	48.0	53.2	65.7	65.2	64.3	50.8
Crude fiber	390.7	546.4	640.2	723.5	719.2	720.5	571.6
Nitrogen-free extract	647.3	738.6	810.3	1,100.9	1,315.6	1,367.7	1,258.6
Total harvest	1,761.0	2,106.0	2,381.0	2,839.4	3,029.0	3,096.5	2,710.4

Soybeans may be cut for hay over a period of several weeks with good results. Other things being equal, soybeans are best harvested when the pods are well filled and the lower leaves turning yellow. The results reported by Dorsey (1918) at the West Virginia Experiment Station show that the dry matter increases more than three times after the blooming stage until the pods are full. Each constituent studied, with exception of the protein, was found to be highest when the leaves had begun to fall from the lower portion of the stems.

TABLE LVIII.—YIELD OF VARIOUS NUTRIENTS IN SOYBEANS CUT AT DIFFERENT STAGES, POUNDS PER ACRE, AT THE WEST VIRGINIA EXPERIMENT STATION

Time of harvesting	Maturity	Green forage, lb.	Dry matter, lb.	Protein, lb.	Fats, lb.	Carbohydrates, lb.	Fiber, lb.	Ash, lb.
Aug. 14	In bloom	7,700	1,305	295	23	520	385	81
Aug. 22	Pods formed	11,240	1,965	445	40	760	615	115
Aug. 29	No pods filling	15,740	3,120	625	60	1,340	945	167
Sept. 4	Pods swelling	16,620	3,305	675	88	1,375	1,020	155
Sept. 12	Pods ⅔ full	16,560	3,805	785	173	1,575	1,090	186
Sept. 19	Pods full, leaves ripening some	18,260	4,000	875	238	1,715	1,190	197
Sept. 26	Leaves gone from 3 in. of stem	19,320	5,100	825	376	2,250	1,370	228
Oct. 3	⅓ pods ripe, ¾ leaves ripe	15,840	4,540	830	347	1,910	1,250	207

CHAPTER XVIII

HAY MAKING

In the preceding chapter a discussion of the proper time for cutting forage crops has been given. The next consideration in the preservation of forage crops to be used for hay purposes is that of curing. Proper curing is essential for the production of hay of the highest grade even though the crop is otherwise properly handled. The successful curing of hay is largely dependent upon favorable weather conditions but the quality of the product is also an indicator of the producer's ability to handle the crop.

Essential Facts about Curing Hay.—In the curing process certain changes take place which materially affect the market and feeding quality of the hay. These changes are necessary in order to secure properly cured hay. However, it is essential that the grower handle the crop in a judicious manner in order that the changes which take place may make possible the production of hay of the highest quality.

In the curing process, (1) a change in plant material and (2) a loss of substance take place. Both of these changes affect the market and feeding qualities of hay.

Changes in Plant Material during the Curing Process.—These changes fall under three heads: (1) reduction of water, (2) enzymatic action and (3) bleaching.

Reduction of Water.—The amount of water in the plants decreases from about 70 per cent in the freshly cut material to about 15 per cent in the air-dried or field-cured hay. Moore, Stone and Olson (1905) in Wisconsin found that when alfalfa was made into hay, the water was reduced from 72.13 to 17.74 per cent. In the case of clover, the water was reduced from 71.56 to 15.33 per cent; timothy, from 63.25 to 19.86 per cent; and brome grass, from 66.83 to 25.44 per cent. The percentage of water evaporated ranged from 41.39 for brome grass to 56.23 for clover.

Swanson (1916) reports that green alfalfa in Kansas contained 72 per cent water while the field-cured crop contained 26 per cent, a loss of 46 per cent in field curing. Headden (1896) in Colorado found the average loss of water in field curing of the first cutting of alfalfa to be 73.14 per cent and for the second cutting 71.08 per cent. Vinall and McKee (1916) give some interesting data in regard to moisture contents of various green field-cured crops. The data as presented in Table LIX are taken from their paper.

TABLE LIX.—PERCENTAGE OF MOISTURE IN GREEN AND FIELD-CURED FORAGE

Crop	Green material, per cent				Field-cured hay or fodder, per cent			
	Number of analysis	Average	Maximum	Minimum	Number of analysis	Average	Maximum	Minimum
Alfalfa	23	71.75	82.03	49.30	21	8.44	16.00	4.60
Red clover	43	70.79	91.78	47.13	38	15.26	31.27	6.02
Timothy	56	61.58	78.70	46.98	68	13.18	28.88	6.12
Kentucky bluegrass	18	65.07	82.53	51.67	14	21.16	32.82	14.30
Corn	16	79.33	93.60	51.50	35	42.18	60.17	22.93
Sorghum	11	79.40	86.38	63.88				

It is thought that some of the samples used in the compilation of the results were allowed to become unusually dry before the moisture was determined, as the moisture content is lower than that commonly found in field-cured forage.

These same investigators have compiled data from various sources showing the moisture content of timothy, alfalfa and red clover at various stages of growth. The average percentage of moisture in the green substance of timothy was as follows: heads not yet visible, 74.4; heads just appearing, 72.94; heads fully out, 70.8; beginning to bloom, 66.7; full bloom, 64.27; past bloom, 59.82; nearly ripe, 59.28; seed fully formed, 54.25; and seed becoming hard, 49.15 per cent. The average percentage of moisture in the green substance of alfalfa was as follows: 18 inches in height, 83.32; in bud, 79.05; in early bloom, 77.84; in half bloom, 74.34; in full bloom, 70.64; bloom fading, 68.29; leaves drying, 65.07 and ripe, 55.92 per cent. The average percentage of moisture in the green substance of red clover was as follows: heads not yet visible, 82.55; just before bloom, 71.96; full bloom, 66.81; nearly out of bloom, 69.46; seed formed, 68.80; nearly ripe, 61.05 per cent. When the first cutting was in bloom the percentage of moisture in the green substance of red clover was 91.78; when the second cutting was in young bloom, 77.52; and when the third cutting was in young bloom, 72.51 per cent.

Amount of Moisture in Hay When Stored.—Vinall and McKee (1916) compiled data from different sources showing the percentage of water in hay when placed in storage. The average percentage was found to be 22.63 per cent. The results shown in Table LX are from their compilation.

The loss of water in curing hay is variable. When field cured and ready for storage, hay has usually lost about 50 to 60 per cent in

weight. This loss includes both reduction in water and reduction in dry matter, the former being much the greater. The loss in water is desirable since hay with too much water deteriorates when stored. In addition, hay containing excessive moisture requires more labor in handling than properly cured hay.

TABLE LX.—PERCENTAGE OF MOISTURE IN HAY WHEN PLACED IN STORAGE

Description of hay	Source of data	Moisture content, per cent
Small samples:		
Bluegrass	Kan.	18.21
Orchard grass and clover mixture	Kan.	16.50
Millet	Kan.	23.76
Clover	Kan.	9.82
Prairie hay	Kan.	12.55
Alfalfa, well cured, average 19 bales	Kan.	6.20
Timothy, cut in 1908	Kan.	26.52
Timothy, cut in 1909	Kan.	22.00
Average of percentages: awnless brome grass, meadow fescue, orchard and tall oat grass, cut 1905	Kan.	15.45
Same cut in 1908	Kan.	30.94
Same cut in 1909	Kan.	31.52
Alfalfa, average of first, second, third and fourth cuttings (124 samples)	Kan.	29.00
Timothy, cut when in bloom	Pa.	36.16
Timothy, cut when nearly ripe	Pa.	31.10
Timothy, red top and red clover mixture:		
In 1901	R. I.	26.89
In 1902	R. I.	25.40
Average	.....	22.63

Rate of Loss of Moisture.—The rate of loss of moisture seems to depend on the crop and on weather conditions, as shown by Vinall and McKee (1916*a*). At Chico, California, the loss of moisture from alfalfa was much more rapid than at Arlington, Virginia. At Chico the temperature is higher and the humidity lower. The results in Table LXI are reported by these investigators.

Loss of Weight in Storage.—After hay is stored, a certain amount of shrinkage takes place. The shrinkage resulting is due to loss of moisture and of dry matter. In the case of well-cured hay the chief loss in storage is caused by reduction in water content. On the other hand, when hay is stored undercured or wet, a large loss results from fermentation. If

TABLE LXI.—RATE OF LOSS OF MOISTURE FROM VARIOUS HAY PLANTS AFTER CUTTING

Crop and location	Moisture loss, per cent				
	½ hr.	1 hr.	2 hr.	3 hr.	4 hr.
Alfalfa at Chico, Cal.	..	17	35	..	69
Alfalfa at Arlington Farm, Va.	6	14	23	28	32
Tall oat grass and orchard grass at Arlington Farm, Va.	5	12	24	30	34
Timothy at New London, Ohio.	6	10	18	25	30
Sorghum at Hays, Kan.	2	5	9	12	13

the crop when stored contains about the same amount of moisture as the atmosphere, there is little change in weight. Forage extremely dry when stored may gain weight. Hay decreases in weight when first stored and recovers some of the loss later. When the atmosphere contains

TABLE LXII.—WATER CONTENT OF FIELD-CURED AND WELL-CURED BARN AND STACK-CURED HAY

	Field-cured hay, maximum per cent	Well-cured barn or stack hay, per cent		
		Minimum	Average	Difference between minimum and maximum water content
Timothy (all analyses)	28.9	6.1	11.6	22.8
Timothy, early to full bloom	28.9	7.0	12.8	21.9
Timothy, late bloom to early seed	21.6	7.0	14.1	14.6
Redtop (all analyses)	28.0	6.8	9.8	22.2
Redtop, in bloom	....	6.8	8.0	
Alsike clover	....	5.3	12.3	
Alfalfa (all analyses)	30.0	4.6	8.6	25.4
Red clover (all analyses)	31.3	6.0	13.0	25.3
Cowpea	....	7.6	9.7	
Soybeans	20.0	6.1	8.6	13.9
Johnson grass	....	...	10.1	
Barley	15.0	6.4	10.0	8.6
Oat	26.5	9.5	12.0	17.0
Rye	....	...	8.1	
Wheat	....	...	8.1	
Prairie	17.1	6.5	10.0	10.6

more moisture than the forage, the latter absorbs moisture from the former, and vice versa. In case of well-cured hay, it may be seen that the moisture content of the hay when stored and the changes in the humidity of the atmosphere largely govern the amount of shrinkage of hay. The data showing the shrinkage of hay as reported by McClure (1920) from a compilation of results from various sources are shown in Table LXII.

Vinall and McKee (1916) have compiled data on shrinkage of hay in storage in various places. Their compilation is given in Table LXIII.

Table LXIII.—Shrinkage in the Weight of Hay during Storage

Crop and treatment	Source of data	Shrinkage, per cent
Alfalfa:		
Cuttings Apr. 19 to Nov. 9, stacked in open until Feb. 11	Ariz.	11.00
Stacked in open 5 mo	Ariz.	23.00
Stacked in open 8 mo	Col.	17.70
Stored in a barn 8 mo	Col.	12.20
Baled in good condition and stored in a barn 3 mo	Kan.	6.20
Average loss	....	14.02
Timothy:		
Stored 10 mo. in a barn	Maine	17.35
Stored 6 mo. in a barn	Mich.	14.38
Stored in a barn until winter (average of a large No. of determinations)	Pa.	25.40
Cut in bloom, stored in a barn 5 mo	Pa.	25.70
Stored in a barn 9½ mo	Utah	8.75
Stored in a barn 9 mo	Utah	15.70
Average loss	....	17.88
Clover:		
Stored in a barn about 6 mo. (average of several determinations)	Mich.	11.60
Stored in a barn about 6 mo	Pa.	24.50
Stored in a barn 5 to 6 mo	Pa.	43.30
Samples buried in a sack and left until winter	Wye, Eng.	15.87
Average loss	....	23.82
Timothy and clover:		
Stored in a barn 6 mo. (average of 4 determinations)	Pa.	20.50
Timothy, redtop and red clover:		
Stored in a barn 6 mo	R. I.	14.10
Average for all crops	....	18.06

The average loss in storage for all the crops studied was 18.06 per cent. However, it is to be noted that great variations in losses existed.

The average loss in shrinkage for alfalfa was 14.02 per cent, and for red clover 23.82 per cent.

That there is not always a loss of hay in storage has been shown by results of experiments. Failyer and Willard (1888) at the Kansas Experiment Station found that a bag of prairie hay buried in a mow of hay gained 0.4 per cent in 4 months. A bag of clover hay similarly stored gained 3.17 per cent in 4½ months. At the Utah Experiment Station, Sanborn (1893) reports that when 4,565 pounds of timothy hay stacked on July 20, 1892, was weighed 9 months later it was found to have gained 1.5 per cent. At the same station 4,090 pounds of clover was stacked on July 15, 1892, and the following April when weighed the gain was 10.7 per cent.

McClure (1920) gives a rather complete résumé of data on shrinkage. The extreme loss of hay due to shrinkage in storage amounted to 44.2 per cent. The minimum loss was only 0.29 per cent. There were actual gains in some experiments varying from 0.4 to 10.7 per cent. The extremes show a range of gain and loss amounting to 55 per cent from time hay is stored until well cured in the barn or stack. It is difficult to state the average amount of shrinkage which will take place when hay is stored. The difficulty is due to the fact that shrinkage depends upon several factors, such as the variation in the time of cutting, method of curing and weather conditions. These factors and causes will bring about great variations. According to Wheeler and Adams (1902) 20 per cent has been allowed at the Rhode Island Experiment Station for shrinkage of hay in storage. However, the tests there show the amount of shrinkage in hay from a check plat to be 14.9 per cent; from the one-third nitrogen plat, 15.7 per cent; and from the full nitrogen plat, 19.6 per cent.

Enzymatic Changes in Composition during Curing.—During the curing process certain changes take place in the composition of the plant as a result of fermentation brought about by enzymes, usually with the development of the characteristic aroma. Holderfleiss (1899) in Germany states that curing hay is not simply a drying process, but that in addition certain fermentation processes take place. Fermentation produces aromatic bodies and diminishes the quantity of crude fiber by increasing the relative amounts of other nutrients, especially nitrogen-free extract. Hay which has undergone proper fermentation has a better flavor, agrees with animals and is more digestible than hay which has cured quickly in the sun without fermentation. Fermentation seems to diminish the amount of pentosans in hay, especially in hay made from grass, but increases the proportion of crude protein.

Emmerling (1897) in Germany packed fresh grass in earthenware jars and covered them. In 24 hours the temperature of the grass increased to 26° C., and remained fairly constant for a while, and then slowly decreased to room temperature. For 4 weeks there was an evolu-

tion of gas consisting of 63 per cent carbon dioxide and 36 per cent nitrogen. The material when removed was brownish in color and had an acid reaction. The amount of nitrogen-free extract and protein was decreased while the other constituents were relatively increased.

Weiske (1897) in Germany compared the composition of normal meadow hay with that moistened and kept at 100° F. for 6 months in open jars, stoppered with corks, and for 1 month in a glass stoppered jar. It was found that no marked change took place in the amount of albuminoid and non-albuminoid nitrogen. However, the amount of digestible protein decreased and the amount of indigestible protein increased. Moisture made the changes more marked. It is probable that the digestibility and nutritive value of the other nutrients are lowered by heating. The author concludes that the diminution is due to some deep-seated changes in the protein and not to simple coagulation.

Fermentation.—It seems that a certain amount of fermentation is desirable in curing hay. Proper fermentation apparently increases the digestibility of the forage and gives it a pleasant aroma and a good flavor. On the other hand, excessive fermentation will lower the quality of the hay. It seems that a high moisture content is necessary for excessive fermentation and that hay properly cured is not likely to be injured by the process. Hay which has been wetted by rain or insufficiently cured, when stored in such condition, often ferments and heats. As a result the quality of the hay is lowered. According to Keable and Wale at Wye. England (McClure, 1920), there is a direct relation between temperature and moisture content of hay. With sufficient moisture the temperature may become very high. However, according to these investigators the dry matter is not likely to be damaged until the temperature exceeds 150° F. Hoffman in Germany (McClure 1920) found that the organic matter of hay is destroyed at a temperature of 226° F. or over.

Spontaneous Combustion.—Hoffman states as follows in regard to spontaneous combustion:

> When spontaneous combustion occurs in clover, heat is generated in the hay, oxygen being taken up from the air and the organic matter transformed into carbon dioxid and water. The water moistens the hay, and the moistened material ferments because of the presence of bacteria. The fermentation also produces carbon dioxid and water, as well as small amounts of hydrocarbons, hydrogen, organic acids, enzymes, etc. Heat is also produced from the fermentation. The fermentation is more rapid if the clover is moistened at the beginning. However, the water produced by the oxidation of the material is sufficient to start it. The fermentation of the hay causes the temperature of 133° F. At this temperature a more violent oxidation takes place and the temperature rises to about 194° F. Other processes then take place which char the material and cause a slow rise in temperature to 226° F. When this temperature is reached, the hay rapidly heats and the charring proceeds rapidly. All these processes

destroy at least half of the material. Theoretically the temperature may reach 374° F.

According to the tests made, clover hay may become ignited at 302 to 392° F. Therefore the temperature may rise sufficiently high to cause spontaneous combustion. Oxygen from the air is essential to combustion.

Bleaching.—Bleaching is caused by the destruction of the chlorophyll by sunlight. When hay is bleached, it becomes brittle; the quality is reduced because of reduced palatability and digestibility, poor color, loss of aroma and loss in weight. The bleaching action seems to be increased by rain and dew.

Loss of Substances during Curing.—In addition to the loss of water in curing of hay there is often a loss in dry matter. This latter loss is due to some process of oxidation as well as to loss of leaves and finer portions of the stems. The investigations of Shuey (1914) show that the loss of dry matter in field-cured alfalfa was 12.0 per cent, while field-cured alfalfa exposed to rain lost 22.8 per cent. The loss of leaves under favorable condition of field curing was 5.6 per cent and when exposed to rain, 17.6 per cent. The results presented in Table LXIV are taken from Shuey.

Table LXIV.—Effect of Field-curing and Rain on Changes in Chemical Analysis of Alfalfa Hay in Kansas (Loss Per Cent)

Treatment	Protein, per cent	Sugar, per cent	Starch, per cent	Fiber, per cent
Laboratory cured (no loss)	17.83	4.18	10.71	27.50
Field cured (12 per cent loss)	13.77	2.25	12.40	30.51
Exposed to rains and field cured (22.8 per cent loss)	11.33	0.75	14.12	36.49

The loss of protein due to field curing and field curing exposed to rain was 32 and 51 per cent, respectively; the loss in sugar content was 53 and 86 per cent, respectively. There was a relative increase in starch and fiber.

Willard (1908) states the loss by weathering during field curing in Kansas is due to fermentation processes, mechanical losses and the dissolving out and removal of substances. It was found that alfalfa exposed to three showers totaling 1.76 inches lost 60 per cent of its protein, one-third of its fats, 41 per cent of its nitrogen-free extract and 28.7 per cent of its ash. The percentage of fiber relatively increased.

Cooke (1900) in Colorado found that the loss of dry matter in the field curing of alfalfa varied from 5.1 to 26.1 per cent, with an average of 11.7 per cent. Unfavorable weather conditions greatly increased the losses.

Table LXV.—Losses Caused in Kansas by the Action of Rain on 100 Pounds of Alfalfa Hay, Assuming That No Fiber Was Lost

	Ash	Protein	Fiber	Nitrogen-free extract	Fat	Total
Original, lb.	12.2	18.7	26.5	38.7	3.9	100.0
Damaged, lb.	8.7	7.5	26.5	23.0	2.6	68.3
Lb. lost	3.5	11.2	00.0	15.7	1.3	31.7
Per cent lost	28.7	60.0	00.0	41.0	33.3	31.7

Short (1889) in Wisconsin found that clover and timothy hay cut July 19 and exposed to the weather lost 4.57 per cent dry matter and 3.68 per cent protein by July 23; 4.61 and 4.10 per cent, respectively, by August 1; and 23.56 and 24.08 per cent, respectively, by September 5.

The loss of hay due to exposure to rain while curing in the field in Germany is shown in Table LXVI as reported by Emmerling (1891).

Table LXVI.—Percentage of Ingredients in Hay Lost by Exposure to Rain

	In cocks, per cent	In swaths, per cent
Loss of total dry matter	18.3	29.4
Loss of crude fat	31.0	41.0
Loss of crude protein	29.0	24.8
Loss of digestible protein	19.8	38.8
Loss of non-albuminoid protein (amides)	9.6	12.2

The losses in cocks as compared with the losses in swaths are approximately as 62 to 100.

The results of experiments indicate that a portion of the dry matter of the growing plants is lost by washing by rains. The loss seems to increase as the plants approach maturity. Trowbridge, Haigh and Moulton (1915) in Missouri found the dry matter of timothy to decrease 394 pounds per acre from the time the seeds were all in the dough stage until the seeds were ripe. The loss is attributed to falling off of leaves and washing by rains. LeClerc and Breazeale (1908) state that plants exude salts upon their surface and that these salts are washed back to the soil by rain. Wheat when ripe was subjected to four rainfalls on separate days. The amount of constituents dissolved from the plants was as follows: nitrogen, 27 to 32 per cent; phosphoric acid, 20 to 22 per cent; potash, 63 to 66 per cent; soda, 46 to 65 per cent; lime, 51 to 59 per cent; magnesia, 54 to 62 per cent; and chlorin, 90 per cent.

Loss of Substance after Storing.—Vinall and McKee (1916) have compiled data from various sources showing the loss in dry matter of corn during storage. Their compilation is given in Table LXVII.

TABLE LXVII.—SHRINKAGE OF TOTAL WEIGHT AND DRY MATTER OF CORN DURING STORAGE

Method of storing	Source of data	Shrinkage	
		Total, per cent	Dry matter, per cent
Shocked as fodder:			
In large shocks outdoors	Col.	73.00	31.00
In small shocks outdoors	Col.	78.00	43.00
Indoors	Vt.	70.80	23.94
Outdoors	Vt.	69.40	28.89
Outdoors	Vt.	43.00	19.00
Outdoors	Vt.	49.00	8.90
Whole plant, outdoors	Vt.	.....	18.00
Yellow dent, outdoors	Wis.	71.29	18.55
Average of 4 varieties, outdoors	Wis.	67.44	16.54
Average	.....	65.24	23.09
Stover, outdoors	Vt.	.....	17.00
Dry fodder stored in a barn	Utah	.....	21.35
Stored as ensilage:			
Whole plant	Vt.	18.00	20.00
Stover	Vt.	.....	21.00
Whole plant	Vt.	.....	18.00
Whole plant, sweet corn	Wis.	19.93	22.04
Whole plant, average of 3 varieties	Wis.	16.13	15.94
Whole plant	Utah	23.80	29.28
Average	.....	.....	21.04

The average loss in dry matter in the shocked fodder was 23.09 per cent and the average loss in dry matter of the ensilage was 21.04 per cent, the maximum being 29.28 per cent and the minimum 15.94 per cent.

Cooke (1900) at the Colorado Experiment Station found that alfalfa stacked for 8 months in the open lost 10 per cent of dry matter and only 2.5 per cent when stored in a barn for the same period. There was no damaged hay in the barn, while there was some in the stack. Calculated on the basis of hay suitable for feed at the end of the 8 months, the loss in the stack was 12.4 per cent while that in the barn was 2.5 per cent. The hay in the stack lost 2 per cent of ether extract, 10.5 per cent of crude protein, 4.4 per cent of crude fiber and 16.8 per cent of nitrogen-free extract.

Sanborn (1893) at the Utah Experiment Station reports that clover hay stacked in the open, stored in the barn, or suspended, lost no dry matter during a period of 9 months. Timothy stored for 9 months in the barn lost 10 per cent of its dry matter while that stacked in the open lost but little. Sanborn (1892*a*) reports a loss of 14.9 per cent of dry matter when a ton of timothy hay was stored for 10½ months in the center of a mow. Another lot of timothy hay placed in a bag and suspended in the barn for 7 months lost no dry matter.

McClure (1920) states in regard to the loss of dry matter of hay in storage as follows:

> There is practically no loss of dry or nutrient matter during the shrinkage of hay while in the barn or stack, provided the hay has been properly cured before it is hauled from the field. Undercured hay, containing an excessive amount of water, is liable to become so hot in the barn or stack that it will become discolored, charred, or, in extreme cases, entirely burned up by spontaneous combustion.

Relation of Changes during Curing to Market Quality.—The better grades of hay should be properly cured by the time they are ready to be sold. The highest prices are paid for hay with good or natural green color. The quality of hay is markedly affected by the methods used in curing and storage, and by weather conditions. When proper methods are used and the weather conditions are favorable prime or high quality hay usually results. Such hay is bright; is as green as possible; has a good aroma; retains its leaves, especially the legumes; and is free from dust or mold. Hay of this grade is comparatively high in palatability, digestibility and feeding value.

In order to obtain high quality it is necessary for the crop to have lost sufficient water to prevent excessive heating when stored or baled. Hay baled when too green brings a low price on the market and there is little demand for it. There seems to be a direct relation between the amount of moisture present in hay and the degree of fermentation and heating. A certain amount of fermentation is desirable as the process seems to make the hay more palatable and digestible, and gives it a characteristic aroma. However, excessive fermentation is undesirable and results in a reduction of dry matter, palatability and digestibility. The hay, moreover, is off color and moldy. Hay containing the proper amount of moisture when stored usually undergoes about the optimum amount of fermentation.

Stained and bleached hay is discriminated against on the market. Such hay is off color and is reduced in feeding value, palatability and digestibility. For proper curing, hay should be so handled as not to be exposed any more than necessary to rain or sunlight. The lack of the desirable green color is especially noticeable in hays which have been exposed to rain and to the sun for too long a period.

The storage of hay is important from the market standpoint. It should be stored so as to prevent damage as far as possible. There seems to be but little loss of dry matter in hay due to storage, provided the crop is properly cured when placed in storage. However, the bulk should be protected from the weather to prevent damage by rain and snow. Hay stacked in the open is usually damaged on the outside and this portion makes a low-grade product. This same fact holds true in the case of baled hay when stored and not properly protected from unfavorable weather conditions. The outside of the bale becomes discolored and the entire bale sells on the basis of the market value of the hay on the exterior. If a hay of high quality is to be placed on the market it is obvious that proper handling is absolutely essential.

FIG. 19.—The quality of hay is often improved by curing in cocks.

Practices in Curing Some of the Principal Crops.—During dry weather hay making is a simple process, while in wet weather the process is more complicated. Under humid conditions two processes are used to hasten the curing. The first is to accomplish more rapid drying of the hay by keeping it well aired, which may be accomplished by turning with a pitchfork or tedder. The second is to place the hay in cocks from the windrow to reduce the surface exposed to rain or dew.

In the humid sections of the country it is a common practice to finish the field curing of hay in cocks. This practice usually produces a higher quality hay than windrow curing, but it is more expensive and laborious. Where a large acreage of hay is harvested under dry conditions, it is a common practice to cure hay from the windrow rather than from the cock. At the present time the greater part of the hay crop is made by allowing the forage to wilt in the swath and then raking into windrows where the

field curing is completed. At times, especially in the western and central part of the United States, the hay crop is completely cured in the swath and lifted from the swath by the loader.

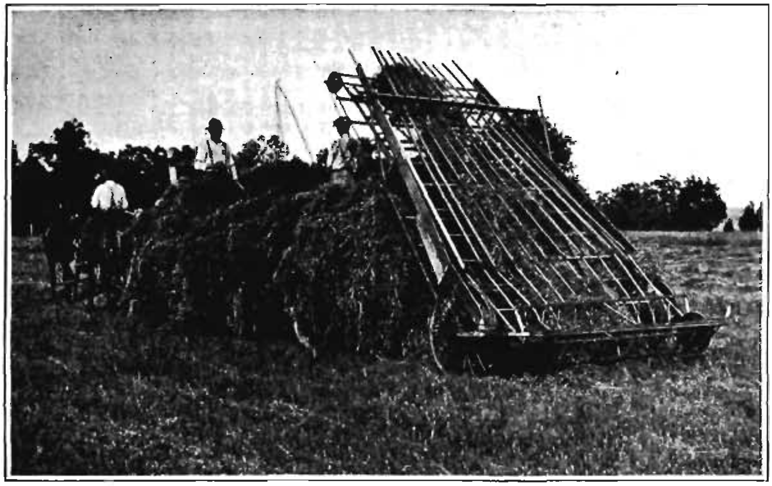

FIG. 20.—Hay loader in operation. (*U. S. Dept. Agr., States Relations Service*).

FIG. 21.—Hay caps help in making high-quality hay when weather conditions are unfavorable.

Legumes.—Since they are more succulent and since the leaves shatter more easily most legumes are more difficult to cure for hay than the grasses. When alfalfa and the clovers are cured, the hay is allowed to wilt somewhat in the swath and then is stirred, if the crop is heavy, by use of the tedder. After a few hours, before the leaves have begun to get

dry and brittle, the hay is raked into windrows and is allowed to remain in this condition until dry enough for storage. If the hay is to be put into cocks, it should be placed there soon after raking.

In the curing of legumes the loss of leaves should be prevented as far as practicable, for the leaves are the most valuable part of the plants. Coe (1917) reports that the leaves of white sweet clover contained 28.20 per cent protein, 3.09 per cent fat, 39.78 per cent nitrogen free extract, 10.92 per cent ash and only 9.28 per cent crude fiber. The stems con-

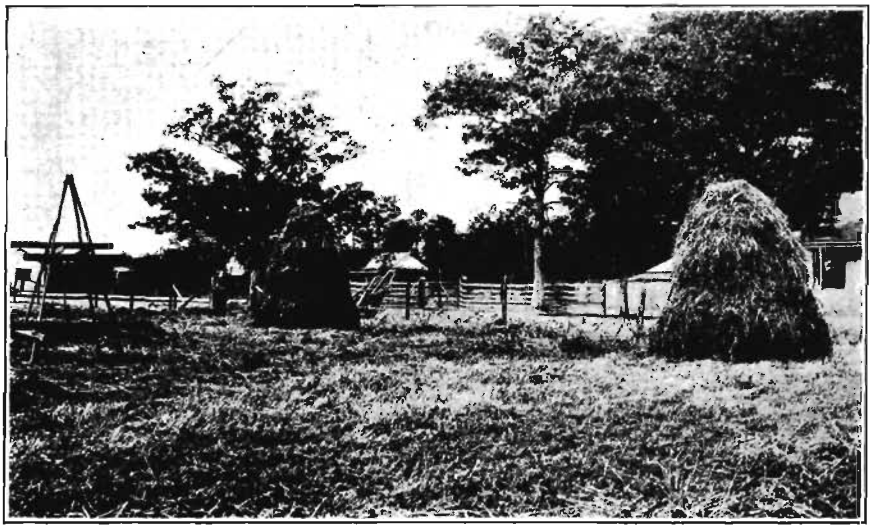

FIG. 22.—Showing frames used in curing cowpea hay. (*U. S. Dept. Agr., Farmers' Bul.* 1153).

tained 10.16 per cent protein, 0.70 per cent fat, 33.08 per cent nitrogen-free extract, 8.08 per cent ash and 39.45 per cent crude fiber. Headden (1906) in Colorado reports alfalfa stems to contain 6.35 per cent protein while the leaves contain 23.33 per cent. Westgate and Hillman (1911) report red clover leaves to contain 24.63 per cent protein while the stems contain only 8.06 per cent. These figures serve to show the high feeding value of the leaves as compared with the stems, and the advisability of using care to preserve the leaves in curing.

Soybean hay can be more easily cured than can cowpea hay. However, with these two legumes, as with alfalfa and the clovers, the object is to prevent the loss of the leaves as far as practicable. In the curing of either cowpeas or soybeans the crop is allowed to wilt in the swath and is put into windrows, where it is left for two or three days. The hay is then placed in small cocks or around perches or pyramids and left until ready for storage.

Grasses.—The grass crop can be cured into hay much more easily than can legumes. The period required for curing is shorter and a loss

from shattering of leaves is less. In favorable hay making weather, especially when the crop is fully developed, the crop may be cut in the morning and stored in the afternoon, but usually the crop is cut one day and stored the next. The general practice followed in the curing of grass crops for hay, if the crop is heavy, is to allow the hay to wilt in the swath and then tedded. A few hours after tedding the hay is raked into windrows, cured and stored. In case the highest grade of hay is desired or the weather conditions are unfavorable, the hay should be placed in cocks as

Fig. 23.—The side delivery rake helps to speed up hay making. (*International Harvester Company of America*).

soon as raked and allowed to cure there. When the crop is allowed to cure in the windrow rather than in the cock, much larger areas can be handled and the hay can be produced more economically. There is, however, some sacrifice in quality by windrow curing.

Summary of General Rules for Curing Hay.—In the curing of hay there is a loss of water; a change in the chemical condition, due to the fermentation, with the development of a characteristic aroma; and bleaching, due to the destruction of chlorophyll. The first two processes are desirable while the latter is not. In curing hay, one should not expose it to the sun any longer than necessary. Hay properly cured with short period of exposure to the sun loses its water comparatively slowly, the fermentation is not excessive and the hay retains the aroma and a desirable green color. Moreover, hay thus cured is palatable and digestible and of high quality generally.

Hay is usually allowed to wilt in the swath, raked into windrows, allowed to cure there and then stored. If the crop is heavy, it is stirred by tedding before raking into windrows. However, under certain conditions the hay is placed in cocks just after raking and allowed to complete the field curing in the cock.

CHAPTER XIX

SILAGE

The practice of ensiling crops was probably not followed by the Romans. It was used by the Germans at an early date and the first recorded attempt to ensile green maize was made in 1861 by Adolph Reihler. In this country the first silo was built by Manly Miles in 1875. In 1876, Francis Morris of Oakland Manor, near Ellicott City, Maryland, built a silo and filled it with corn. In both of these instances the silo was built in the ground. The work of F. H. King was started in 1891 and has done much to make the silo and the practice of ensiling crops a success. Rapid progress has been made in building silos and in making silage from green crops. At the present time an enormous acreage of crops is ensiled and fed to live stock each year.

Economy of Silage.—Silage is used throughout the United States but especially in the dairy sections of the country. However, it serves as an excellent food for beef cattle and sheep, as well as for dairy stock. According to Woodward (1913) the reasons for the popularity of silage are:

1. More feed can be stored in a given space in the form of silage than in the form of fodder or hay. (2) There is a smaller loss of food material when a crop is made into silage than when cured as fodder or hay. (3) Corn silage is a more efficient food than corn fodder. (4) An acre of corn can be placed in the silo at less cost than the same acre can be husked and shredded. (5) Crops can be put in the silo during weather that could not be utilized in making hay or curing fodder. (6) More stock can be kept on a given area of land when silage is the basis of the ration. (7) There is less waste in feeding silage than in feeding fodder. Good silage properly fed is all consumed. (8) Silage is very palatable. (9) Silage, like other succulent feeds, has a beneficial effect upon the digestive organs. (10) Silage is the cheapest and best form in which a succulent feed can be provided for winter use. (11) Silage can be used for supplementing pastures more economically than can soiling crops, because it requires less labor, and silage is more palatable. (12) Converting the corn crop into silage clears the land and leaves it ready for another crop.

Crops for Silage.—A crop suitable for making silage should give a high yield of material which, when placed into the silo, will produce a nutritious, palatable and easily digestible feed. The principal silage crop of the United States is corn. It probably constitutes more than 90 per cent of the total amount. In the central and southern Great Plains,

sorghum is the chief silage crop. The droughty conditions of these regions are better suited to sorghum production than to the production of corn. In the southern states, corn, sorghum, Japanese cane, pearl millet and other crops are used for silage purposes. Sunflowers have recently come into prominence as a silage crop. According to Vinall (1922) they are adapted to the northen sections of the country and the higher altitudes of the western states. Sunflowers are much more resistant to frost than corn.

Various legumes, such as cowpeas, soybeans and the clovers, are sometimes used for silage purposes. Such crops when ensiled alone often make a feed which has an undesirable odor. However, when they are ensiled with corn or sorghum in the proper proportion, a higher quality of feed results. A leguminous crop is often grown with the corn crop and the two harvested and ensiled together. The two crops may be grown separately and mixed at time of filling the silo, and the proportion should be not more than one part legume to one part of corn or sorghum.

Yields.—Hutcheson and Wolfe (1922) report the yields of various crops for silage under Virginia conditions. The results are shown in Table LXVIII.

TABLE LXVIII.—YIELD PER ACRE OF GREEN MATERIAL, DRY MATTER AND FOOD CONSTITUENTS OF CERTAIN CROPS GROWN FOR SILAGE PURPOSES, 4-YEAR AVERAGE

Crop	Yield		Food constituents, lb.			
	Green material, tons	Dry matter, lb.	Protein	Fats	Crude fiber	Carbohydrates
Cocke's Prolific corn	16.04	6,962.59	646.70	122.15	1,856.40	4,016.35
Boone County White corn	13.66	6,830.00	617.09	130.90	1,570.35	4,256.16
Early Amber sorghum	12.12	5,398.48	322.59	154.26	2,104.13	3,876.93
Mammoth Yellow soybeans	10.15	5,239.03	965.91	207.34	1,638.98	2,006.95
Whippoorwill cowpeas	8.36	3,123.07	522.22	74.15	963.30	1,265.39
Golden millet	5.63	3,982.59	278.45	75.30	1,378.94	1,958.85

These results indicate that under the conditions of this investigation corn and soybeans are the most desirable crops for silage purposes. In the sections of the country where the rainfall is deficient the comparative valuation of sorghum would probably be higher.

The comparative yields of sunflower, corn and sorghum silage are given in Table LXIX, as reported by Vinall (1922).

TABLE LXIX.—COMPARISON OF THE YIELDS PER ACRE OF SUNFLOWER, CORN AND SORGHUM SILAGE

Locality	Yields per acre, tons		
	Sunflower	Corn	Sorgo (cane)
State College, N. M.[1]	20.0	15.0	20.0
Newell, S. D.[1]	12.8	8.2	11.3
Redfield, S. D.	15.2	10.4	15.5
Guelph, Ont., Can.	17.1	15.8	16.7
Guelph, Ont., Can.	20.3	16.9	17.2

[1] Produced under irrigation.

Composition of Silage.—The comparative composition of sunflower, corn and sorghum silage as compiled by Vinall (1922) is given in Table LXX.

TABLE LXX.—COMPARISON OF THE COMPOSITION OF SUNFLOWER, CORN AND SORGHUM SILAGE

Kind of silage	Number of samples	Constituents, per cent					
		Water	Ash	Crude protein	Crude fiber	Nitrogen-free extract	Ether extract
Sunflower	14	77.8	2.4	2.2	6.3	10.4	0.9
Corn	730	70.9	1.4	2.4	6.9	17.5	0.9
Corn stover	6	80.7	1.8	1.8	5.6	9.5	0.6
Sorghum	16	77.6	1.7	1.5	7.1	11.0	1.1

In percentage of ash, sunflower silage ranks first, while in the case of crude protein, sunflower silage and corn silage are about the same but higher than either corn stover silage or sorghum silage. Corn silage leads in nitrogen-free extract with 17.5 per cent, while sorghum silage contains 11.0 per cent and sunflower silage 10.4 per cent. In percentage of fats, sorghum silage leads.

Digestibility of Silage.—The data in Table LXXI seem to show that sunflower silage and sorghum silage are less digestible than corn silage.

Rate of Planting Silage Crops.—Crops to be used for silage should be planted at a somewhat thicker rate than those grown for grain purposes. However, the rate of planting should not be so large as to interfere too greatly with grain production. The rate of planting will of course vary with the kind of crop, climate and productivity of the soil.

Table LXXI.—Digestible Nutrients in 100 Pounds of Sunflower, Corn and Sorghum Silages (Vinall, 1922)

King of silage	Digestible nutrients, lb.		
	Crude protein	Crude fiber and nitrogen-free extract	Ether extract
Sunflower	1.09	9.30	0.91
Corn	1.39	17.39	0.67
Corn stover	1.04	10.78	0.45
Sorghum	0.87	12.92	0.82

Changes in Plant Material during Growth.—The composition and yield of the corn plant at different stages of growth are shown by Smith (1898). At the Michigan Experiment Station, 100 representative stalks of dent corn were selected at different dates and various data were secured, as shown in the Table XXLII.

Table LXXII.—Weight of the Leaves, Stalks and Ears of 100 Corn Plants, and the Percentage of the Total Dry Matter Contained in These Parts at Different Stages of Growth

Time of cutting	Weight in lb.				Percentage of total dry matter		
	Entire plant	Leaves	Stalk	Ears	Leaves	Stalks	Ears
Aug 24 (in milk)	201.75	85.0	67.75	49.00	36.41	34.27	29.32
Aug. 31 (roasting ear)	195.00	76.0	66.50	52.50	33.63	25.52	40.85
Sept. 7 (glazed)	210.25	82.0	69.50	59.75	30.03	25.53	44.44
Sept. 14 (ripe)	176.50	49.5	64.00	63.00	21.77	31.91	46.32

The results in Table LXXII show that while the weight for the stalks remained fairly constant, the relative weight of dry matter of the leaves decreased and that of the ears increased. The greatest weight of plant was produced when in the glazed stage. The dry matter of the stalks remained about constant, while the relative amount in the leaves decreased and that in the ears increased.

The protein and albuminoids in the leaves decreased as maturity was approached, while that in the ears increased. These constituents in the stalks showed some variation, but the percentages for the early and late stages were about the same. The nitrogen-free extract in the leaves decreased as the plants ripened, while the content of the stalks and ears increased.

Hutcheson and Wolfe (1922), at the Virginia Experiment Station, report the food constituents in different varieties of corn at various stages of growth. The results are shown in Table LXXIII.

TABLE LXXIII.—A COMPARISON OF THE FOOD CONSTITUENTS IN VARIETIES OF CORN PLANTED AT DIFFERENT DATES, 4-YEAR AVERAGE

Name of variety and date of planting	Stage of development	Percentage on moisture-free basis			
		Protein	Fats	Crude fiber	Carbohydrates
May 3					
Boone County White	Mature	8.38	2.25	20.14	65.45
Leaming	Mature	9.32	2.45	18.01	66.72
Cocke's Prolific	Glazed	7.92	1.89	26.53	59.73
Virginia Ensilage	Glazed	9.07	1.83	25.87	58.81
May 10					
Boone County White	Glazed	9.21	1.87	23.61	61.50
Leaming	Glazed	9.10	2.23	21.23	63.47
Cocke's Prolific	Dough	9.30	1.61	27.28	56.91
Virginia Ensilage	Dough	9.36	1.64	26.72	57.05
May 17					
Boone County White	Dough	9.66	1.67	27.80	55.89
Leaming	Dough	9.29	2.04	22.82	61.55
Cocke's Prolific	Milk	9.27	1.70	27.95	56.29
Virginia Ensilage	Milk	9.46	1.50	29.02	55.06
May 24					
Boone County White	Milk	9.35	1.84	27.58	56.71
Leaming	Milk	9.41	2.05	24.09	60.32
Cocke's Prolific	Grain forming	8.73	1.69	27.92	56.67
Virginia Ensilage	Grain forming	9.64	1.98	27.42	55.60

There is a tendency for the carbohydrates to increase as the plants mature. The crude fiber remains nearly constant in the case of the prolific varieties and decreases somewhat in the grain varieties. The fats increase and the protein has a tendency to decrease. The analyses were made of the entire plant. The Boone County White and Leaming varieties are usually planted for grain purposes. The Cocke's Prolific and Virginia Ensilage varieties are classed as prolific varieties and are commonly used for silage purposes.

Sorghum.—The composition and yield of sorghum at different stages of maturity were determined by Smith (1898).

The weight of the entire plant increased as maturity was approached. In a consideration of the various parts, it was found that the tops and leaves increased in weight with approach of maturity, while the weight of the stalks decreased somewhat. The percentage of dry matter of the

TABLE LXXIV.—WEIGHT OF LEAVES, STALKS AND TOPS OF 100 SORGHUM PLANTS, AND THE PERCENTAGES OF THE TOTAL DRY MATTER CONTAINED IN THESE PARTS AT DIFFERENT STAGES OF GROWTH

Time of cutting	Weight in lb.				Percentage of total dry matter		
	Entire plant	Leaves	Stalks	Tops	Leaves	Stalks	Tops
Aug. 25	104.50	17.50	81.75	5.25	20.85	71.07	8.08
Sept. 1	92.50	17.00	70.00	5.05	20.85	68.74	10.41
Sept. 8	105.00	20.50	77.50	7.25			
Sept. 15	109.00	22.00	78.50	8.50	17.11	65.93	16.96

leaves and stalks decreased as maturity was approached, but the content in the tops increased. The percentage of dry matter in the leaves was about equal to that in the tops, while the stalks contained nearly four times as much as either. The investigation showed that the sorghum plant has 65.93 per cent of its dry matter in the stalks at maturity, but only 19.8 per cent of the protein. At this stage of development the leaves contain 45.56 per cent protein, and the tops 34.64 per cent. Of the albuminoid nitrogen, 39.33 per cent is in the leaves, 36.38 per cent in the tops and 24.29 per cent in the stalks. The percentage of protein in the leaves and stalks decreases with maturity, while the content of the tops increases. Of the nitrogen-free extract, 73.39 per cent is found in the stalks at maturity, while the leaves and tops contain 11.74 and 14.88 per cent respectively. With maturity the percentage increases in the tops and slightly decreases in the leaves and stalks.

Willaman and others (1919) studied the composition of the sorghum plant at various stages of development, beginning their studies when the panicles were appearing and ending when the seeds were mature. It was found that the percentage of dry matter increased up to maturity. The fiber of the dry matter decreased as the soluble carbohydrates increased. The percentages of crude protein, ash and ether extract remained practically the same throughout growth.

Sunflowers.—Anthony and Henderson (1920), in West Virginia, report the composition for sunflowers at different stages of growth as shown in Table LXXV.

The fat, fiber and carbohydrates increased to the dough stage, after which there was a slight decrease. The percentages of ash and protein show some variation but they are larger in the mature than in the dough stage, while the moisture percentage shows but a slight decrease.

Shaw and Wright (1921) found that as the sunflower plant approaches maturity the percentage of water decreases, the dry matter increases, while the total protein and albuminoid protein show a tendency to

decrease. The reducing sugars rise and then fall, while the non-reducing sugars steadily and rapidly decrease. The percentage of starch is small and irregular throughout the period of growth.

TABLE LXXV.—AVERAGE CHEMICAL ANALYSES OF SUNFLOWERS AT DIFFERENT STAGES AS GROWN IN MARYLAND

Stage of growth	Moisture, per cent	Ash, per cent	Protein, per cent	Fat, per cent	Fiber, per cent	Carbohydrates, per cent
Bud	80.75	1.53	1.41	0.55	5.48	15.76
Full blossom	86.69	1.59	1.21	0.50	3.90	10.01
Petals dropping	83.97	1.78	1.12	0.66	5.56	12.47
Dough stage	83.34	1.69	1.10	1.06	4.96	12.81
Mature	84.26	1.74	1.61	1.36	4.75	11.03

Stage of Cutting.—Crops for silage should be cut when the largest amount of digestible nutrients will be secured to the acre, rather than the greatest amount of green material. Crops cut when too green are likely to produce a lower amount of food constituents per acre and to give a low-grade, watery silage.

FIG. 24.—A good field of silage corn. Corn is the great silage crop of the country. (*Virginia Crop Improvement Association*).

Corn.—Smith (1898) in Michigan states that in order to secure the greatest yield per acre of valuable nutrients, corn should be cut for silage when the crop is fully glazed and when the early ears are well ripened.

Ladd (1890) found that the nutrients produced per acre of the corn crop increased until the plants matured. According to Jordan (1895) corn should be allowed to mature before being harvested for silage. It was found that the total quantity of dry matter per acre in corn at matu-

rity was nearly 2½ times as great as the quantity obtained at the silking period 37 days earlier.

At the Virginia Experiment Station, Hutcheson and Wolfe (1922) report that the highest yield of food constituents in the corn crop was reached at the glazed stage.

TABLE LXXVI.—YIELD IN POUNDS PER ACRE OF THE FOOD CONSTITUENTS OF THE CORN CROP WHEN CUT AT DIFFERENT STAGES OF DEVELOPMENT, 4-YEAR AVERAGE

Date of planting	Stage of development	Yield per acre, lb.				
		Dry matter	Protein	Fats	Crude fiber	Carbohydrates
May 3						
Boone County White	Ripe	6,425.18	530.91	147.67	1,265.21	4,240.29
Leaming	Ripe	6,039.36	567.48	142.68	1,129.28	3,989.15
Cocke's Prolific	Glazed	8,259.46	655.94	160.06	2,190.63	4,928.06
Virginia Ensilage	Glazed	7,190.47	651.94	141.56	1,776.04	4,314.47
May 10						
Boone County White	Glazed	6,830.55	617.09	130.90	1,570.35	4,256.16
Leaming	Glazed	5,848.29	525.16	133.52	1,228.22	3,729.73
Cocke's Prolific	Dough	6,962.59	646.70	122.15	1,856.40	4,016.35
Virginia Ensilage	Dough	6,757.10	598.96	118.14	1,717.94	3,962.86
May 17						
Boone County White	Dough	5,840.89	528.97	103.97	1,542.88	3,385.59
Leaming	Dough	5,026.34	450.36	115.22	1,039.04	3,218.62
Cocke's Prolific	Milk	6,136.54	557.51	116.06	1,662.19	3,528.28
Virginia Ensilage	Milk	6,280.69	562.54	99.16	1,801.05	3,496.23
May 24						
Boone County White	Milk	5,110.12	437.42	89.84	1,394.02	2,991.42
Leaming	Milk	5,568.44	509.66	124.43	1,252.17	3,467.48
Cocke's Prolific	Grain forming	5,498.46	450.91	97.05	1,495.20	3,192.18
Virginia Ensilage	Grain forming	5,799.69	516.16	121.97	1,570.22	3,298.35

Sunflowers.—In the case of sunflowers, Shaw and Wright (1921) state that the crop is best harvested for silage when the rays are dry and partly fallen. Anthony and Henderson (1920) in West Virginia seem to think that sunflowers are best for the silo when the seeds are in the dough stage.

Vinall (1922) advises cutting sunflowers for ensilage before the seeds have reached the hard dough stage. In dry climates the plants should be harvested at an earlier stage of development than in humid regions.

Most writers advise cutting sunflowers for silage when only 50 to 60 per cent of the stalks are in bloom. It is inadvisable to cut the crop when too green, as the silage made is likely to be watery and the shrinkage percentage high.

Sorghum.—Scott (1916) states that grain sorghums should be cut for silage when the seeds are in the stiff dough stage. Woodward and others (1914), reporting Kansas data, advise the harvesting of the sorghum crop for silage when the seeds have become hard. Vinall and Getty (1920) find that the largest quantity of cured forage from sorghum is secured when the crop is harvested after the seeds are well formed, and it is at this stage that the highest acre yields of protein, carbohydrates and fats are also secured.

Good Practice in Making and Preserving Silage.—In the production of silage crops a study should be made of the crop or crops best adapted to the conditions under which the silage is to be made.

There is a gain in food constituents in most crops nearly up to maturity. Sometimes, however, there is a loss in the case of crops harvested too late, and it is, therefore, important to know the best stage for cutting the crops and the best stage for storage in the silo. The results of experiments indicate that corn for silage should be cut when the crop is in the glazed stage, and sunflowers and the sorghums when the seeds are in the dough stage.

The harvesting of the various crops should be done in the most inexpensive and practicable manner. As a rule, crops for silage can be more profitably harvested by the use of machines especially made for the purpose. The ordinary corn binder can be profitably used in harvesting corn, sunflowers and sorghum for silage.

On being placed in the silo the crop should be thoroughly packed to exclude air. This precaution is important, as silage improperly packed is likely to mold, to become sour and to lose much of its feeding value. Air is necessary for the fermentation processes to take place; and if the air is excluded by thorough packing, excessive fermentation will be avoided. It seems that some loss in food constituents in the silo is unavoidable but the loss should be reduced to a minimum.

To prevent deterioration in the feeding of silage from the silo, at least 2 inches should be removed from the top each day.

Changes in Silage.—When crops are placed in the silo, the temperature of the bulk rises on account of fermentation processes, and a certain amount of acid is produced with a reduction in nutritive matter.

Loss in the Silo.—Numerous experiments have been conducted showing the loss of material in the silo. Smith (1898) in Michigan reports the loss occurring in silage when the crop was ensiled at various stages of growth. The loss in dry matter from corn harvested at different dates was as follows: August 10, 20.08 per cent; August 25, 24.81 per cent;

September 6, 22.01 per cent; and September 15, 26.80 per cent. The silage was removed in November just after the time of ensiling. The loss of protein varied from 2.76 per cent for corn cut August 25, to 23.65 per cent for corn cut September 15. There was a loss of albuminoid nitrogen and a gain of amide nitrogen during the experiment. The greatest loss of nitrogen-free extract was with the corn harvested August 25.

Smith (1898) has complied the data showing the losses resulting from ensiling the corn crop. The compilation is shown in Table LXXVII.

Table LXXVII.—Losses of Dry Matter, Protein and Nitrogen-free Extract at Various Stations

Source	Dry matter, per cent	Protein, per cent	Nitrogen-free extract, per cent
Vermont Report, 1889	14.67	10.12	23.58
Vermont Report, 1891	20.00	13.00	
Vermont Report, 1892	18.00	11.60	26.90
Vermont Report, 1894	20.00	12.00	30.00
New Jersey Bulletin 19	18.00		
Pennsylvania Report, 1889	10.76	26.42	14.00
Pennsylvania Report, 1890[1]	20.36	11.23	34.02
Wisconsin Report, 1889	16.54		

[1] Average of 15 trials in Wisconsin, Pennsylvania and Missouri.

King (1896) states: "The necessary loss of dry matter in corn silage is considerably less than 10 per cent, and is probably as low as 5 to 8 per cent."

CHAPTER XX

SPECIAL-PURPOSE CROPS

Since farming operations depend upon a number of factors, some of which are under the control of the farmer and others of which are beyond his control, it is often necessary to alter to some extent the original plan of the system of farming. It is usually easy to plan a rotation of crops but more difficult to grow the crops according to the plans; and often a substitution is made. Crops substituted for the regular crops are sometimes called "special-purpose" crops.

Catch Crops.—These crops often become very important, as they may be used to furnish feed when other crops fail. It is not unusual for the main crops of a rotation to fail on account of drought, inopportune planting, use of poor seed or any one of a number of reasons. It is in many cases advisable to plant some crop to occupy the land until it is time for planting the next regular crop of the rotation. Such crops are called "catch" crops.

In sections where the growing season is long, it is possible to grow a catch crop between two regular crops of the rotation without any interference with the rotation. Cowpeas or soybeans are sometimes planted between wheat crops when wheat follows wheat in the rotation.

Cover Crops.—In a discussion it is difficult to separate cover crops from green manuring crops. If a cover crop is turned under to enrich the land, it then becomes also a green manuring crop. Cover crops serve a useful purpose in protecting land from washing and in utilizing plant nutrients when they become available. In this way losses from leaching are prevented.

Cover crops may be seeded to make their growth either in the summer or in the winter and early spring; that is, they may be classed as summer and winter cover crops. Cover crops are usually seeded with some other crops and their growth in this way does not reduce the number of crops ordinarily secured.

Green Manure Crops.—Green manuring is one of the oldest methods of increasing the productivity of the soil. Any crop which is turned under to increase the yielding power of the soil may be classed as a green manuring crop. If the crop is turned under, the productivity of the soil is usually increased, various fertilizing elements used in producing the crop are returned to the soil and a supply of organic matter not originally in the soil is added. The organic matter furnishes food for the organisms

in the soil and in addition it may improve the structure and water-holding capacity of the soil. Legumes are valuable green manuring crops because under proper conditions they are hosts for bacteria, which have the power of assimilating atmospheric nitrogen.

Some Effects of Green Manuring.—It sometimes appears that green manuring has a detrimental effect on the crop immediately following, and several reasons have been given to explain this effect. Brown (1912)

FIG. 25.—Roots of sweet clover. When such roots decay, the organic matter of the soil is increased and the soil is left better aërated.

found under Iowa conditions that turning under large quantities of green manure crops, such as clover, cowpeas and rye, interfered with the ammonifying organisms in the soil. It is suggested that organic matter introduced into the soil may alter the specific relationship of the organisms. That there may be a reduction in the available nitrates of the soil owing to their being consumed by growing organisms has been shown by Martin (1921) at Cornell University. Hill (1915) in Virginia found that the presence of green manures, such as clover and soybeans, resulted in an increased number of bacteria, greatly improved the rate of nitrate formation and increased crop growth.

Fred (1916, 1918) in Wisconsin found that the germination of some seeds was seriously injured by planting soon after turning under green manuring crops. The detrimental effect seemed to disappear in 2 to 3 weeks after the crop had been turned under. It is sometimes stated that turning under green manuring crops increases the soil acidity and thus produces a harmful effect on the succeeding crop. Hill (1919) in Virginia

found that where the acidity of the soil was increased by the turning under of green crops, the increase soon disappeared. In other words, the acidity is transitory. It was found that turning under green manure crops was not harmful to vigorous nitrate production, nitrogen fixation and crop growth.

Under ordinary conditions it would seem that, with the judicious handling of green manure crops and the crops which follow, no permanent harmful effects should ensue from green manuring. In fact, it seems that in practically all instances, beneficial results are to be expected.

Types of Green Manuring and Cover Crops.—According to Piper and Pieters (1922) these crops may be classed under four divisions:

(1) Those occupying the ground exclusively throughout the summer. This type of green-manure crop is naturally the most expensive, since no crop can be removed from the field that season. A green-manure crop of this sort is seldom to be recommended except where very poor soil must be brought to a state of sufficient productivity to allow a regular rotation to be established. (2) Subsidiary crops, those seeded with a main crop, such as clovers in grain, and turned under in the fall or the following spring. Such crops involve little extra expense besides seed and may even be grazed moderately without serious harm. (3) Stubble crops, those seeded on grain stubble after harvest for turning under in the fall or spring. Cowpeas, soybeans, vetch, buckwheat, rape, turnips, and such crops are most commonly used in this way. (4) Winter cover crops. For this purpose crops must be selected that will endure the degree of cold common in the locality.

The practice of green manuring is a good one and has a place on many farms of this country. However, according to Pieters (1917, pages 162–190), in the semi-arid sections but little benefit is to be derived from the practice. Green manuring will increase yields in practically all cases in the other sections of the country. The value of the increase in yield is often not sufficient to equal the forage value of the green manure crop. Therefore, the crop intended for green manuring is frequently cut for feed and only on poor or inconveniently located soils is summer green manuring practiced.

Time of Turning under Green Manure Crops.—In determining the proper time to turn under a crop for green manuring purposes, one should consider both the green manure crop and the effect on the succeeding crop.

The nutrients contained in the green crops become available with the decomposition of the material when turned under. Martin (1921) at Cornell University has found that rapid decay of the green crop is desirable for large yields of the succeeding crop. It was also found that nutrients did not accumulate until a considerable decay of the incorporated crop had taken place. Hill (1915) also found under Virginia conditions that the nitrogen rapidly passes into the nitrate form as the decay processes advance. It seems that succulence of the crop is necessary for the most

rapid decay. At the same time the total amount of nutrients and organic matter, and the effect on the succeeding crop, must be considered as well as the rapidity of decay. In other words, if a green manure crop is turned under when too young and succulent, the greatest benefit will not be derived. Martin (1921) studied the effect of turning under rye, oats and buckwheat at different stages of growth. It was concluded:

> Using as measurements the rapidity of humus formation, the accumulation of nitrates, and the increased availability of the plant nutrients, the subsequent crop growth proved that the greatest rapidity of decomposition and the greatest benefit to the soil were achieved by the use of green manures at the half-grown stage. This is true for all three of the green manures used.

From results of turning under rye, oats, crimson clover and winter vetch at five different stages of growth in Virginia during a period of three years, Hill (1922) states that the best stage for turning under rye and oats was when the crops were half grown. However, it was best to turn under crimson clover and winter vetch when the plants were in full bloom. Penny and MacDonald (1910) at the Delaware Experiment Station found that thin stands of crimson clover growing on poor soils acquired a large part of their nitrogen during the last month of growth. However, thick stands growing on rich soils acquired but little of their nitrogen during the last month and could well be turned under before maturity is reached without loss to the succeeding crop.

It seems that the proper stage of growth for turning under green manures will vary with the crop and conditions. As a general rule, the crops should be turned under after a considerable growth has been made but before maturity is reached.

It is generally advisable to turn under the green manure crop at least 2 to 3 weeks before the succeeding crop is to be planted. This practice gives the green manure an opportunity to decay to some degree, allows time for the preparation of a good seedbed and enhances the chances for an increased moisture supply in the soil. The green manure crop removes much water from the soil and often the ground is dry when the crop is turned under.

Not only is the time of turning under green manure crops important from the standpoints of preparation of the seedbed and decay of the materials, but the effect of the green manure on the germination of the seed should be considered.

Choice of Special-purpose Crops.—In the selection of a crop to be used for a catch crop, cover crop or green manure crop, certain facts should be kept in mind. Where it is feasible to use a legume, it is to be preferred to a non-legume, as the former will usually add nitrogen to the soil and make a more nutritious forage. The crop used should (1) make a fair amount of growth of nutritious forage; (2) it should grow quickly and

mature early; (3) it should be aggressive, having ability to choke out weeds and grow under adverse conditions; and (4) it should be one that can be seeded cheaply and easily handled. In addition, if the crop is to be used for green manuring, it should have ability to add nitrogen.

Yield.—The quality and the amount of forage produced are important when the crop is to be used either for feed or for green manuring. A high tonnage of forage of high quality is desirable in either case.

Type of Growth.—Crops which mature early and grow quickly are usually required. Special-purpose crops are generally grown between the main crops in the rotation, and for this reason it is necessary to have rapidly growing, early-maturing plants. When a cover crop, such as crimson clover, is grown, the land is often put in corn the following spring. When the growing season is short, it is necessary to plant the corn crop early. If the best results are to be secured from the crimson clover as a green manuring crop, it must be well developed by the time it is turned under. In case wheat is followed by wheat and a crop such as soybeans grown between the two wheat crops, it is necessary that the soybeans develop rapidly if a large yield is to be secured.

Aggressiveness.—Special-purpose crops should be able to grow under adverse conditions. They must be aggressive. Such crops are usually planted where other crops have failed or where the productivity of the soil is low. It is sometimes necessary for these crops to compete with certain persistent weeds; and plants which cannot thrive under these unfavorable conditions are seldom selected for catch crops or for green manuring purposes.

Cost of Seeding and Ease of Handling.—Special-purpose crops should be crops which can be seeded cheaply. The cost of the seed and preparation of the seedbed should be taken into consideration. In the case of green manuring crops, the ease of turning under is an important item. Many farmers who use such crops have limited capital, and since the crop usually brings in no immediate returns, the cost is of some concern. The seedbed should be easily and quickly prepared since the growing period for such crops is sometimes short and they are often seeded when there is a rush of other work.

Principal Cover and Green Manure Crops.—The principal leguminous cover and green manure crops in the approximate order of their importance, according to Piper and Pieters (1922), are red clover, alfalfa, alsike clover, sweet clover, cowpeas, peanuts, soybeans, velvet beans, crimson clover, field peas, vetch, Japan clover, bur clover and white clover. Other legumes sometimes used are beggarweed, grass peas, fenugreek and horse beans. The non-leguminous crops used are rye, oats, barley, wheat, buckwheat, millet, rape, mustard and turnips. Rye is the most common non-legume used as a cover and green manure crop. In the East, wheat, barley, oats and buckwheat are sometimes used. The other non-legumes

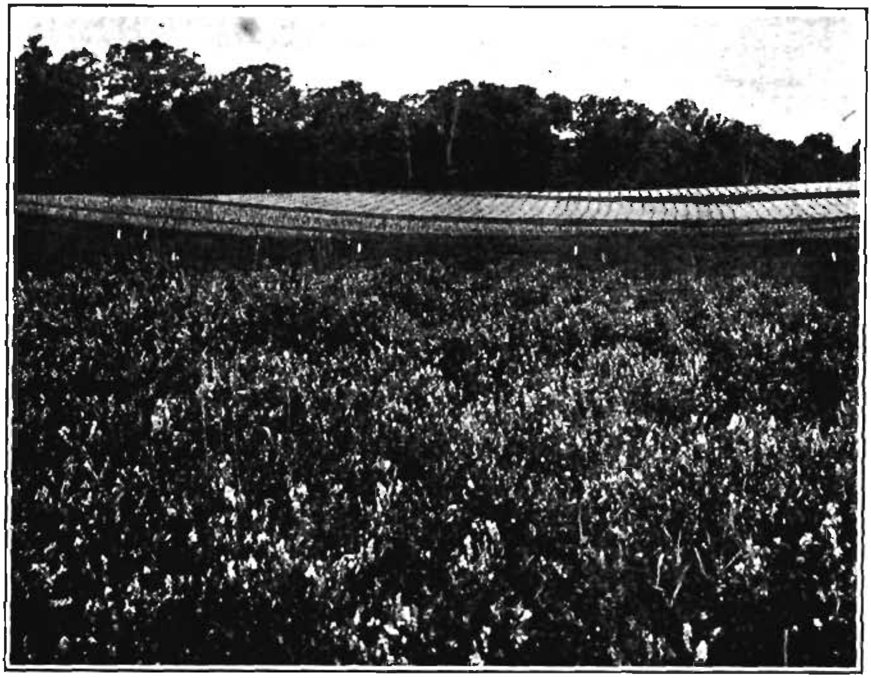

FIG. 26.—Winter vetch in the foreground. This is a hardy winter cover crop, splendid for green manuring.

FIG. 27.—Turning under rye for green manure. (*U. S. Dept. Agr., Forage Crop Investigations*).

named above are seldom used in this country as cover and green manure crops.

Distribution of Special-purpose Crops.—Piper and Pieters (1922) give the following distribution of the various special-purpose crops:

Cotton belt..........	Winter crops	Bur clover Crimson clover
	Summer crops	Cowpeas Soybeans Velvet beans
Clover belt..........	Winter crops	Hairy vetch Rye
	Summer crop, red clover	
Northwest coast.....	Red clover, alsike clover Spring vetch	
Atlantic Coast section	Crimson clover Hairy vetch	
Limestone area.......	White sweet clover	
California orchards... (winter crops only)	Vetch Peas Sour clover	
Northwest apple section	Alfalfa Red clover Hairy vetch	

Results from Green Manuring.—Many facts have been secured and observations reported in regard to the use of crops as green manures. A review of the results of the experiment stations of this country pertaining to green manuring has been ably presented by Pieters (1917, pages 62–82).

Green Manuring in the South.—The experiments reported from the South included those from Alabama, Arkansas, Georgia, Mississippi, Missouri, North Carolina and Tennessee. The results from Alabama and Georgia show that, considering only the first succeeding crop, turning under the entire green manuring crop does not pay. However, the residual effect has not been studied. The following conclusions are drawn from the experiments conducted in the South:

1. The turning under of a leguminous crop or the stubble and residues of such a crop results in an increase, sometimes large, in the next succeeding crop.

2. Turning under a heavy crop of green plants, especially under conditions of dry weather or of imperfect working of the soil, may depress yields below those obtained from turning under the stubble only.

3. Cowpeas grown as a catch crop in corn may depress the yield of the corn. This seems to dedue to lack of moisture.

4. The residual effect of whole crops of cowpeas and velvet beans turned under is markeb, while that of the stubble is sometimes evident, but slight.

5. Considering only the effect on the first succeeding crop it is not profitable to turn under a full stand of green manure.

Green Manuring in the Atlantic Coast Section.—In the Atlantic Coast section most of the work has been done with crimson clover. A small amount of work has been done with alsike clover, red clover, cowpeas, soybeans and vetch. The results reported from this section include those from Connecticut, Delaware, Maryland, Massachusetts, New Jersey and Rhode Island. The chief crops used to measure the effects of green manuring were potatoes and corn, with wheat and oats of very minor importance. It was found that a legume benefits the following crop of corn or potatoes, the benefit being especially noticeable in case of the latter. The conclusions given for this section are:

The addition of nitrogenous fertilizers did not always bring the yield on the non-legume plot up to that from the legume plot.

Rye was compared with clover as a green manure crop to precede potatoes and corn by the Connecticut, Maryland, and New Jersey stations and the clovers were generally found to be superior.

The entire clover crop turned under was found by the New Jersey station to yield a crop of corn containing more protein, fat, and carbohydrates than a corn crop on clover stubble, but the total amount of these feeding stuffs obtained in the two years was much greater when the clover was used for hay.

Green Manuring in the Northeastern Section.—In the Northeastern division are included results from the Province of Ontario, Illinois, Indiana, Iowa, Michigan, Minnesota, New York, Ohio and Wisconsin. The chief crops used to measure the value of green manures were wheat and corn with oats and potatoes of subordinate rank. Red clover was the chief crop used as a green manuring crop or in rotation. In Canada, red clover proved beneficial to the following wheat crop, and it had a marked residual benefit. When clover was used as an annual catch crop, the effect of turning it under was noticeable for three successive crops. In Minnesota it was found that a catch crop of clover benefited the following wheat crop. Some results were reported for cowpeas, alfalfa and timothy sod. Illinois reports no benefit from a cowpea catch crop in corn and sometimes none when cowpeas were grown as a summer green manure crop. Rotations containing clover gave higher yields than those from which it was absent and higher yields than continuous cropping. The results secured in Ohio and Illinois indicate that cowpeas and clover were able to supply nitrogen for the succeeding crop. Pieters states in conclusion as follows: "As a whole it can be said that the results obtained at the State stations in the Ohio and Mississippi valleys have been less striking than those reported from Canada and have often been negative or the evidence has been of doubtful value."

Green Manuring in the Western Section.—The Western section includes the Great Plains, the Intermountain region, the Pacific Coast states and the western province of Canada. The states from which results are reported are California, Colorado, Kansas, Nebraska, North Dakota,

South Dakota and Wyoming. In this section moisture supply rather than organic matter seems to be the limiting factor. The various legumes and rye and millet were used as green manures. The chief crops were wheat and corn With the exception of the results from California little, if any, benefit was observed from green manures. In some cases increased crops were secured in Kansas after cowpeas and sweet clover. However, more extensive tests in Canada show as good results after fallow as after turning under a green manure crop; some tests show even better results. The yield of grain following a hoed crop was greater than that following a green crop or stubble or a legume turned under. However, clover and timothy gave beneficial results in Kansas. The conclusions in part are:

In many cases rye and millet turned under gave as good results as the turning under of field peas. The turning under of an alfalfa sod was generally followed by larger crops than were taken from adjacent land on which alfalfa had not been grown.

In California the turning under of green crops in spring resulted in better grain yields the following winter than were taken from fallowed land. In this case, however, there was really a summer fallow succeeding the turning under of the green manure. Here, too, rye gave better results than the legumes.

Under irrigation in southern California the legumes appear to have fully filled the place of nitrogen gatherers generally assigned them, since the yields following legumes were larger than those after barley, even when reinforced with considerable applications of nitrates.

General Summary of Results from Green Manuring.—Pieters gives as follows a general summary of all the experiments reviewed:

South and Atlantic Coast Sections.—

While most of the experimental work in the South and Atlantic Coast sections is open to serious objection when critically considered, a body of evidence remains cumulative in its effect, to show that leguminous green-manure crops increase the yields of following crops under the conditions prevailing in those sections. There is no adequate evidence to show whether or not this result would also be obtained by the use of nonleguminous green-manure crops. The results at the Rhode Island station point at least to the possbility that under some conditions the roots of a grass sod may be quite as efficieint as a legume. Some of the Michigan and Minnesota work might be interpreted in the same way, though there is little evidence to this effect at present. At the Maryland station better yields were produced after rye than after crimson clover.

In a general way, it has been shown that care must be exercised in the turning under of the green-manure crop to avoid injury, but the relation between different methods of treatment and the various following crops remains to be studied further.

While it has been shown that there is a marked residual value to a green-manure crop, the value of this has not been worked out. In fact, the subject has been touched on at but one station and that inadequately. This residual value of various green-manure crops for the different succeeding crops in the rotation is a promising field, awaiting agronomic research.

North and West.—

In the North there is convincing evidence of the value of red clover as a green-manure crop under the conditions prevailing in the Provinces of Ontario and Nova Scotia. The fact that there is a pronounced residual value has also been brought out. Farther west in our Ohio and Mississippi valleys evidence of the value of green-manure crops is mostly wanting. Contrary to the Canadian results, there is even some evidence against concluding that it has value and much of the work is unsatisfactory. As a rotation crop, clover has been shown to be beneficial, but there is need for more exact work to show, if possible, how much of this benefit is due to the clover as a legume and how much must be ascribed to the growing of crops in a rotation. The question is not one of the benefit to be derived from a rotation; that is well established. The important matter is whether a legume in such a rotation gives better results than would be obtained from growing a crop of similar habit but a nonlegume, as timothy. On this phase of the question the record throws no light.

While in Illinois part of the evidence is negative, this becomes even more the case in the Northwest, where there is no adequate evidence to show that a leguminous crop is better than a nonlegume as green manure, nor even that turning under a green-manure crop results in better yields than summer fallow. It does not appear that any serious effort has been made to determine whether this result is due to the possible fact that the soils of our West and Northwest still contain a sufficient supply of humus, or to the different moisture conditions prevailing.

It is a fact of some interest to observe that, excluding the region west of the Rocky Mountains, the value of a legume as green manure, as shown by the published work of the American experiment stations, decreases roughly from southeast to northwest. There can be no doubt of the value of cowpeas and similar crops in the South, nor of crimson and red clover in the East and Northeast, but this feeling of assurance is changed to one of uncertainty as the records from the Ohio and Mississippi valleys are studied and finally to the conviction that in the Dakotas and in the Canadian Northwest the conditions do not warrant the use of a leguminous green-manure crop.

CHAPTER XXI

PLANT ASSOCIATION AND COMPETITION

In the cultivation of two or more crops mixed interesting phenomena occur. It seems that certain plants do well when seeded in mixtures, while others are suited only for growing alone. This statement is as true of the cultivated as of the wild plants. The variations existing among plants, their struggle for existence and the elimination of those unfit to survive under a particular environment have been recognized to be of importance since Darwin formulated his Law of Natural Selection.

Plant Association in Nature.—Everywhere in nature it may be observed that certain plants grow and thrive well together while others are found to crowd out their neighbors.

The association of bluegrass and white clover is well known in the northeastern section of the country. In the rich limestone valleys and uplands these two plants thrive in association as soon as the land is cleared. In the southern states, Bermuda grass, and Japan clover and bur clover are found growing together on some soil types. Bermuda grass is very aggressive and persistent; but not sufficiently so to prevent these two clovers from growing in association with it. This mixture serves the same useful purpose to the southern farmer that bluegrass and white clover does the northern farmer. On the acid soils of the New England states bent grasses and redtop thrive while bluegrass is grown with comparative difficulty. If these soils are limed, the bluegrass increases. On the poorer acid soils the fescues predominate over the grasses which require a more favorable soil environment. When the soil conditions are improved, the fescues decrease as the other grasses increase.

Sorrel thrives on an acid soil; but if the soil is limed, the economic plants often crowd it out. Hawkweed, frequently a serious pest in pastures, readily crowds out the native grasses. However, by cultivation or the application of dry salt, the hawkweed may be eradicated and the native grasses will return. Chickweed is often a serious pest in cultivated crops and is difficult to eradicate. In the grain fields of the West, wild mustard and wild oats cause serious damage since they are capable of competing with the grain crops.

Plant Association in Cultivation.—In the production of cultivated crops it is often desirable and advisable to grow certain plants in association. In other cases the reverse is true. At one time there may be a

mutual benefit to be derived from association; again, one group of plants may profit at the expense of another group, while still again there may be a competition among all the groups and none profit by the association.

Choice of Plants for Associated Growth.—In the selection of plants for growing in association, the characteristics of the plants, the purpose for which they are grown and the environmental conditions under which they are to be grown should be taken into consideration.

Deep- and shallow-rooted plants are often grown together based on the theory that the feeding area will be increased. Certain plants are particularly suited to certain soils. There is a great variation in the soil of the same field. Therefore, when plants are seeded in mixtures, one group of plants may make a good growth on one part of the field and another group on another part. In cases where it is not necessary or advisable for all of the plants of the mixture to make their maximum growth at the same time, groups of plants which mature at different seasons of the year often do well together. This condition is found to be the case in pasture mixtures. On the other hand, the plants used in meadow or hay mixtures should mature at about the same time.

Examples of Successful Association.—A well-known example of successful association is that of white clover and Kentucky bluegrass. It seems that wherever bluegrass grows naturally, white clover also grows in the same way but the reverse is not true. Some seasons there is a much larger proportion of white clover to bluegrass than in other seasons. The reason why white clover practically always appears in association with bluegrass cannot be definitely stated. However, it seems that the soil and climatic conditions most favorable for the growth of bluegrass are also favorable for the growth of white clover. Both of these plants grow best on rich soils in cool, moist climates.

Hutcheson (1911) found that the 2-year average yield per acre of timothy alone was 3,857 pounds; of redtop alone, 3,307 pounds; of timothy and redtop, 4,460 pounds; and of timothy, redtop and red clover, 5,440 pounds. The probable reasons for increases in yields of the mixtures are that the roots of the different species occupied different portions of the soil more completely than single species. The roots of redtop and timothy grow comparatively shallow while those of the clover grow deep. Redtop will grow under more adverse conditions than timothy, while timothy is more aggressive than the clover. All these plants mature about the same time and are, therefore, suitable for mixtures. The clover may also directly or indirectly supply nitrogen to the grasses.

It is a common practice to sow legumes, such as soybeans, cowpeas and vetch, with sorghums, Sudan grass and the millets. Often the yield of the mixture is not so large as the non-legume growing alone. However, the mixture produces a forage which is more nutritious than the non-legume when grown alone. This fact overcomes to some degree the

smaller yield which sometimes results. And it is to be remembered that the mixture often gives a higher yield than either crop planted alone. The non-legume is frequently valuable in such mixtures in holding the legumes erect, where legumes which have a vining tendency are used.

Other Examples of Association.—Plants which are unsuited for growing in association are seldom grown together for any length of time. However, plants may do well in association under some conditions and not under other conditions. Park, Willard and Borst (1922) in Ohio found that soybeans and corn did much better when grown together in seasons of abundant moisture than in dry seasons. This fact indicates that moisture was the limiting factor in this experiment.

FIG. 28.—Corn and soybeans growing in association for the purpose of "hogging-off."

The results secured at the Virginia Experiment Station show that a mixture of cowpeas and soybeans gave lower yields of hay than soybeans alone but higher than cowpeas alone. The experiments were conducted under conditions considered favorable both to soybeans and cowpeas. Such a mixture is more easily harvested and cured than cowpeas alone. The soybeans aid in supporting the cowpeas and the mixture is more easily handled in harvesting than cowpeas alone. Therefore, the seeding of cowpeas and soybeans in combination may prove successful or unsuccessful, depending on conditions.

Mammoth clover and orchard grass do not make as good a combination as red clover and orchard grass. The red clover matures earlier than mammoth; and since orchard grass ripens early in the summer, the former is better suited for growing in combination with it. On the other hand, mammoth clover is more desirable than red clover for growing in mixtures which contain timothy as the principal hay grass. The fact

that red clover matures earlier than timothy makes it less satisfactory as a companion plant than mammoth, which matures with timothy.

A practice that has been followed to a very limited extent in the United States, but more extensively in Canada, is that of planting grain crops in mixtures, called *maslin*. A mixture that has given very good results is barley and oats. It seems from the review of the experiments by Warburton (1915) that in some instances mixtures gave better results than the crops seeded alone, while in other instances the reverse was true. Warburton gathers for his review that:

(1) Grain crop mixtures may be expected to yield more than the grains composing them, if there is only a slight difference in the yield of the components when grown separately, but if the components differ considerably in yield the product of the mixture is likely to be intermediate between them. (2) The rate of seeding for the mixture should not be materially, if any, greater than for the components when sown separately. (3) Obviously, the highest yielding varieties which will mature at the same time should be chosen.

However, in the seeding of grain crops together, not only should the yield be considered but the ease of handling and disposing of the product should also receive consideration.

How Plants May Benefit by Association.—The benefit to be derived by the association of certain plants may be shown by the data obtained by growing legumes and non-legumes together. Lyon and Bizzell (1911) at Cornell University grew timothy alone and with alfalfa and red clover, and oats alone and with Canada field peas. The results of their analyses show the non-legumes growing in association with the legumes to contain more protein than the non-legumes growing alone. Lipman (1912), in New Jersey, studied the effect of association of legumes and non-legumes by growing the plants in cylinders, in pots in the greenhouse, and in the field. In order to determine whether nitrates pass by diffusion from the legumes to the non-legumes, small pots, some glazed and some unglazed, were sunk in the soil in a larger pot. The legume was planted in one pot and the non-legume in the other. It was found that "under favorable conditions non-legumes associated with legumes may secure large amounts of nitrogen from the latter, even though this may not be indicated by an increased proportion of nitrogen in the dry matter of the non-legume." However, legumes seem to vary in their ability to supply nitrogen to non-legumes. At times it seemed that the development of the legume was hindered by the non-legume, while at times the reverse was true. The amount of nitrogen present seems to affect the mixed crops materially. Other things being equal, the greater the amount of available nitrogen at the disposal of the crops, the greater will be the relative yield of the non-legume and less the relative yield of the legume. When factors other than the supply of combined nitrogen are limiting

production of the crops, the development of the non-legume may be depressed rather than increased by presence of the legume.

Ellett, Hill and Harris (1915) found, under greenhouse conditions in Virginia, that bluegrass growing with white clover and timothy growing with red clover did not contain any more protein than when the non-legumes grew alone. The second year the timothy and the timothy-and-clover plats were reseeded and crops produced from the reseeding were analyzed. The timothy growing alone contained 22.24 per cent protein while that growing with red clover contained 26.98 per cent protein. This difference may have been due to the decomposition of the clover of the previous year. In the greenhouse, beans growing with corn increased the yield of dry matter and the percentage of nitrogen in the corn. However, in the field, the beans reduced the yield of corn 30 per cent. The reversal of results is attributed to an insufficiency of water.

Evans (1916) in an investigation conducted at New London, Ohio, found non-legumes growing with legumes to be higher in protein than when growing alone.

The results of experiments in regard to the growth of legumes and non-legumes in association are not in entire agreement. However, the indications are that when there are favorable conditions for growing, and especially when nitrogen is the limiting factor in plant development, non-legumes growing with legumes contain a higher percentage of protein and produce a higher yield than when growing alone. Where the association is beneficial, a portion of the nitrogen added to the soil by the legume may be used by the non-legume.

How Plants May be Injured by Association.—Plants may be unsuited for associative growth because of environmental conditions or because of differences in the plants themselves. Lipman (1912), in New Jersey, has shown that under conditions of limited supply of available nitrogen, the growth of a non-legume growing with a legume is depressed. On the other hand, in the presence of a plentiful supply of combined nitrogen, the relative yield of a non-legume growing in association with a legume is increased and the relative yield of the legume decreased.

It has been shown in Chapter XV that weeds decrease the yield of crops by using plant nutrients and water that might otherwise be available to the crops. Some plants seem to be more aggressive than others and because of this fact crowd out the less aggressive kinds. One plant may produce a substance or substances toxic to associated plants. This idea is supported by results secured by Bedford and Pickering (1911) in England in that it was found that grass inhibited the growth of fruit trees. Under the conditions existing in the United States this toxic effect does not seem to exist to any great extent. The effect of the shading of one crop by another is a factor to be considered in the selection of plants for mixtures. Some plants are greatly improved by shade, while

others are not. Orchard grass thrives well in shady places, while the growth of Kentucky bluegrass is depressed under such conditions.

Influence of Change in Soil on the Plant Population.—Environmental factors play an important part in the growth of plants. It is a well-recognized fact that certain plants are especially adapted to certain environmental conditions. The effect of the soil on the plant is often very marked and a change in the soil often shifts or changes the kinds of plants which will thrive best on it.

Cowles (1909) in England states that the most important factors contributing to changes in plant populations are changes in the humus content of the soil and an increase or decrease in the amount of shade. Other factors important are plant invasion and topographical changes. Geological changes affect plant succession, but they are of course very slow in their action.

Hall (1910) in England studied the flora on plats which had received certain different fertilizer treatments for a period of 50 years. It was found that phosphate and potash fertilizers encouraged the growth of clovers and increased the proportion of these plants to others growing in association. On the plat receiving ammonium sulphate the shallow-rooted grasses like sheep's fescue, bent grass and sweet vernal became dominant. Sorrel was abundant on the plats on acid soils which received potash. The distribution of hops, barley and potatoes was studied in reference to the mechanical analysis of the soil. It was concluded that the structure of the soil as shown by the mechanical analysis was the chief cause determining the association of the plants studied. It is pointed out that the structure and the size of particles are important in their effect on the water supply, temperature and humidity. Soil acidity is considered an important factor in determining the type of plant which will grow on a given soil. At Woburn, barley refused to grow but spurrey did well on acid plats, while this latter plant grew but little on the non-acid plats.

Frickhinger (1904–1905) also found in Germany that the physical condition of the soil affects the flora. The so-called lime-loving plants studied failed to thrive on a calcareous soil which was made porous by the addition of quartz. These same plants grew well on a siliceous soil which had been made compact by the addition of loam and a little calcareous clay.

White (1920) has studied the behavior of clover on various acid soils in Pennsylvania. On some of the acid soils there was good growth of clover while on others the crop was a failure. It was also found that clover failed on some of the alkaline soils. The so-called acidity of soils is apparently due to various causes. This may explain the growth of clover on some acid soils and failure on others.

Hartwell and Pember (1918) in Rhode Island found that rye did well on a so-called acid soil while barley did not. The acidity was found to be

due to active aluminum; and when this was precipitated, both rye and barley grew well. The precipitation of the active aluminum was brought about by the addition of phosphates or of lime.

Hartwell and Damon (1917) at the Rhode Island Experiment Station found that on plats seeded to a mixture of timothy, redtop and red clover, after a period of 2 years the predominating plant on the unlimed plats was redtop. On the limed areas timothy was the predominating grass and clover was abundant in all plats. In another test it was found that liming increased the percentage of brome grass and orchard grass in a mixture of these two grasses with tall meadow oat grass, while the percentage of tall meadow oat grass was decreased. It was also noticed that liming increased the growth of clover and decreased the development of sorrel. When a mixture of timothy, redtop and clover was seeded on a no-nitrogen plat, the plants were mostly clover and some redtop. On the one-third ration of nitrogen plat the plants were mostly redtop and timothy and some clover; and on the full ration of nitrogen plat timothy predominated, while the redtop and clover were practically crowded out. Where a mixture of timothy and redtop was seeded and different nitrogenous fertilizers applied, the proportion of timothy to redtop was greatest where nitrate of soda had been used.

Hartwell and Damon (1914) also give data to show the relation of a number of plants to so-called soil acidity. It was found that on a very acid soil, Kentucky bluegrass, orchard, sheep's fescue, tall fescue and timothy grasses could scarcely live. These grasses were largely replaced by weeds. On the other hand, redtop and Rhode Island bent grasses made their best growth on the very acid soil. The clovers, such as mammoth, white and alsike, responded readily to liming, especially on the plat which received ammonium sulphate. On the nitrate of soda plat the effects of liming on these plants were not so noticeable. However, alfalfa and sweet clover responded to liming to a marked degree on both of the fertilizer plats.

Pipal (1916) in Indiana found that an abundance of red sorrel (*Rumex acetosella*) in a field indicates an unfavorable condition of the soil, such as acidity, insufficient organic matter, insufficiency of mineral nutrients or inadequate drainage. Under such conditions the ordinary crops fail to do well while the growth of sorrel is not seriously interfered with. The sorrel, therefore, forces out the plants which cannot compete under the existing conditions. The correction of the unfavorable condition allows the crops to compete with the sorrel. Liming the soil does not injure the sorrel but makes the conditions of growth more favorable to ordinary crops. White (1913) found the same results in regard to liming in its effect on the growth of sorrel in Pennsylvania.

Aggressiveness in Plants.—Aggressiveness or the ability to hold the soil against weeds and other competitors should be a very important

characteristic of all perennial meadow and pasture crops. This characteristic should also be true of many annuals. Successful plants are those which are aggressive enough to grow better under the conditions under which they are sown than competing plants can grow. The aggressive propensities of plants are an advantage under many circumstances. This characteristic makes it easier to secure a stand and to obtain a good growth under comparatively adverse conditions. Hoevsoer, the aggressiveness of certain plants may be a disadvantage under wme conditions. Some plants are so aggressive that they crowd out other plants with which they are seeded, and they may be so aggressive and persistent as to make their eradication difficult.

Many plants seem to be more aggressive when brought under new environment than they were in their natural ahbitat. Many of our weeds are of this nature. Among them may be mentioned the orange hawkweed, Russian thistle and the penny cress or Frenchweed. Among the economic plants may be cited Kentucky bluegrass, Bermuda grass, white clover, Japan clover and bur clover. Under cultivation, alsike clover seems to be more aggressive than red clover, redtop more aggressive than timothy and in many places the bent grasses and Canada bluegrass more aggressive than Kentucky bluegrass.

Among the grain crops buckwheat is very aggressive, growing on soils and making good yields where the small grains sometimes fail to do well. Rye grows better under adverse conditions of soil and climate than wheat and oats. Oats are less resistant to cold than wheat, but they seem to do better than wheat on poorly prepared seedbeds and under other unfavorable soil conditions. Sorghum will produce a good yield of grain or forage under conditions too dry for good development of the corn plant. Chess is more resistant to winter-killing than oats. Under conditions too adverse for the oat plant, chess often grows in the place of the oat crop; thus arises the common belief that "oats turn to chess." Under conditions favorable for the oat crop the chess plants are held in check.

In the southern states Bermuda grass and Johnson grass often become pests because of their aggressiveness, but they serve very useful purposes for grazing and hay. However, if it is desirable to cultivate the land which is sown to either of these grasses, it is difficult to do so because of their persistence. Bermuda grass and Johnson grass are so difficult to eradicate that land which is used for other crops is seldom seeded to either of them.

Among the aggressive and persistent weeds which are difficult to eradicate even under cultivation may be mentioned quack grass, nut grass or coco weed, and Canada thistle. The orange hawkweed and the field hawkweed are very aggressive weeds, being especially serious in pastures; but they are easily eradicated by cultivation.

CHAPTER XXII

PASTURE MANAGEMENT

Although live stock production is vitally dependent upon pastures, little progress in better pasture methods has been made. Nearly all ideas in regard to pasture management are based on observations rather than on results of actual experimentation. Investigation in pasture management, therefore, offers a fertile and practically untouched field for research work.

Kinds of Pastures.—According to C. V. Piper, a pasture may be defined as a field or area covered with grass or other plants (commonly herbaceous) and used for grazing animals.

A classification of pastures, according to Piper, is as follows:

1. Permanent
2. Temporary
   - Seedling
   - Stubble
   - Crop
3. Rotated
4. Aftermath

A *permanent* pasture is one covered with perennial or self-seeding annual plants and such pastures are kept for grazing indefinitely. The bluegrass, Bermuda and lespedeza pastures are good examples of permanent pastures. *Temporary* pastures are those used for grazing during a short period, not more than one crop season. For such pastures, crops such as rape, rye, cowpeas, millet and Sudan grass are used. A *seedling* pasture refers to a field of wheat, rye and so forth, in which animals are placed to graze on the young growth. A *stubble* pasture refers to a harvested field of wheat, corn and so forth, in which animals are placed to consume the crop refuse and weeds. A *crop* pasture refers to one on which the crop is allowed to mature before the animals are turned in. Under this head are included fields of such crops as corn, soybeans and velvet beans, which when matured are utilized as pastures for hogs, sheep, cattle and other kinds of live stock. If a crop pasture is pastured by hogs, it is said to be *hogged off*. A *rotated* pasture is one used for a few years, usually 2 or 3, and then plowed, in order that crops may be planted. *Aftermath* pasture refers to the second growth on a harvested meadow.

In addition to the above kinds of pastures may be mentioned *tame* and *wild* or *native* pastures. The former are those covered with do-

mesticated grasses and other plants, while the latter are those areas covered with native plants useful for grazing; and when extensive, such areas are called *ranges*.

Permanent pastures require much less work and much less fence than rotated pastures. Rotated pastures usually carry more live stock per acre; and as lands become more valuable, it may pay better to rotate pastures. In all parts of the United States, however, farmers generally use their poorer lands for pasture instead of pasturing the rotated fields.

FIG. 29.—Good pastures are the basis of economic production of beef and dairy products. (*Courtesy Virginia State Dairymen's Association*).

Permanent pastures may at times be supplemented by pasturing other fields but there is no very important dairying or meat producing section in America that does not depend primarily on pastures that last many years. In the northeastern fourth of the United States, Kentucky bluegrass is the great pasture plant. In the arid regions the native grasses furnish pasture on land that is too dry to farm.

Pastures may also be classified according to the type of forage plants predominating in them such as bluegrass, Bermuda grass or alfalfa.

Importance of Pastures.—According to Piper, more than half of the total feed consumed by live stock in this country during 1919 was furnished by pasturage. The estimated cost of pasturage is about one-half as much as harvested forage; therefore, pasturage, constitutes the only really cheap feed.

Goldenweiser and Ball (1918) report as a result of a study of the 1910 Census, that 36.2 per cent of the total farm land of the United States is devoted to crops, 33.2 per cent to pastures and 30.6 per cent to other purposes. In other words, there were 91.5 acres of pasture land in the United States for each 100 acres of crops. These figures do not include temporary or rotated pastures.

Live stock workers are agreed that cattle, horses and sheep are generally not profitable without pastures and that even hog production is more profitable where good pastures can be had. Under certain conditions other methods of handling cattle, such as soiling, may be profitable but these cases are few and usually depend for their successful operation upon an exceptionally high price for products sold or upon very cheap labor. There are no great live stock producing sections without pastures and pasturage will probably always be one of the most important factors in economic live stock production.

Essential Qualities of Pastures.—It is generally desirable that pastures be made as enduring as possible. Permanency of pasturage calls for a mixture of grasses that are either very long lived or that are capable of reproduction under pasture conditions. A good pasture should start growth early in the season and continue to produce until late in the fall. Not only should the grasses be palatable and nutritious but they should present variety and give abundant growth. They should also form a continuous, compact turf that will withstand much trampling by animals. A variety of plants that will provide for growth under both moist and dry soil conditions is also advantageous. The deep-rooted grasses and clovers can, therefore, be advantageously included with the shallow-rooted ones such as bluegrass and white clover. No single grass can make an ideal pasture. Kentucky bluegrass and Bermuda grass more nearly approach ideal pasture grasses in their respective localities than any of the other single grasses, but even these have their periods of low production, and mixtures of other plants which will serve as supplements during short periods are advantageous.

Treatment of Pastures.—The treatment of pastures should vary with the type of pastures and to a certain degree with the kind of animals pastured.

Grazing.—Jardine (1915) states that the most common causes of deterioration in the native western pastures are overstocking and premature grazing. Lack of well-distributed watering places often causes too heavy grazing and trampling in areas near such places. Jardine suggests as a means of improving these pastures: (1) Avoid grazing any of the pasture while the land is wet in the spring and when the principal forage plants are just beginning growth. (2) Limit the animals to the number it is believed the whole area will support in good condition for feeders. (3) Keep animals from certain areas each year until after the forage plants have seeded. (4) Control and distribute the stock by fences, well-distributed watering places and salt troughs so as to minimize congregation in large herds. (5) Watch the vegetation on the area as a whole to find out whether the best forage plants are increasing or decreasing; and increase or decrease the number of animals as may be

necessary to bring the pasture, or each division of it, to its maximum production. These suggestions refer especially to bunch grasses.

Cotton (1910) states that in New York and New England dairy pastures depreciate much more rapidly than beef pastures. He attributes this depreciation of dairy pastures to the fact that dairy pastures are more often overstocked and advises against turning cattle on pastures in the spring until the pasture will give a full feed without other forage supplement.

As the result of pasture experiments conducted at the Virginia Experiment Station on a limestone soil and on a bluegrass-redtop sod, Carrier and Oakley (1914) found that: (1) Very little benefit was derived from cultural treatment by disking and harrowing, and this practice could not be recommended. (2) Heavy grazing gave 1,485 pounds of gain on 2.5 acres of land in 3 years. Light grazing gave 838 pounds of gain in the same time on an equal area. At the close of the 5 years' experiment the heavily grazed field had a more even turf and was much freer from weeds than the lightly grazed field. (3) Very little advantage was secured by grazing cattle in different fields alternately as compared with continuous grazing on the same field.

Since heavy grazing is not practicable on pastures used for finishing fat cattle, these authors recommend that pasture areas most densely weed infested be grazed closely with young cattle or sheep for 2 or more years until the sod has improved. It would seem that under the conditions of these experiments heavy grazing is preferable to light grazing, but overstocking should be avoided. Land may be said to be overstocked if the animal cannot get sufficient feed from it to give or keep up production. If overstocking is kept up too long, there is not sufficient leaf and stem growth remaining to maintain the life processes of the plants. As a result many of the bunch grasses are killed, but overstocking does not injure the stand of creeping grasses. Overstocking is evidenced by the increased growth of weeds and by the dying out of those economic plants most palatable to animals.

Fertilizing.—Etheridge (1919), at the Missouri Experiment Station, states that "when long-established bluegrass becomes unthrifty, the destruction of weeds, the application of stable manure, and the reseeding of the scantiest patches, are in average cases the most practicable means known for its improvement." As a result of the use of fertilizers on bluegrass pastures in Virginia, where gain in weight of steers was used as a measure of results, Hutcheson and Wolfe (1919) obtained marked results from the use of acid phosphate and farmyard manure as shown in Table LXXVIII.

It will be noted that there was a greater gain on the unfertilized field the first year after the manure was applied than on the manured plat. This condition was probably due to the fact that the fresh manure made

the grass objectionable to the cattle and they failed to graze as closely as on the unfertilized field. The poor results obtained from bone meal may be due to the low availability of this material.

TABLE LXXVIII.—GAIN IN ANIMALS IN POUNDS ON 2½-ACRE FIELDS UNDER DIFFERENT FERTILIZER TREATMENTS

Year	Group I, lb.		Group II, lb.		Group III, lb.	
	10 tons manure per acre	No fertilizer	300 lb. acid phosphate per acre	No fertilizer	250 lb. bone meal per acre	No fertilizer
1913	260.50	345.50	185.0	174.0	188.00	120.00
1914	334.00	239.00	220.0	160.0	252.00	359.00
1916	417.75	230.25	551.0	261.5	383.50	486.50
1917	413.00	142.50	399.0	127.5	374.75	246.75
Totals......	1,425.25	957.25	1,355.0	723.0	1,198.25	1,212.25
Gain........	468.00	......	632.0	.....	−14.00	

Since phosphorus is usually the limiting element in plant growth in the limestone sections of Virginia these figures would indicate that pastures may be improved by top-dressing with the fertilizers which give paying results on hay and small grains in the section. These fertilizers were applied early in the spring just before new growth commenced. The same authors found that lime applied to sparse bluegrass pastures greatly improved the sod.

The fact that more plant nutrients are removed from the soil when dairy products are taken away than when beef is sold, according to Cotton (1910), may also account for the more rapid depreciation of dairy pastures. It would seem that it is more important for the dairyman to give attention to keeping up the productivity of his pastures than it is for the beef producer. It is a common belief among beef producers that young growing cattle are harder on pastures than mature cattle. This belief may be based on the fact that young cattle assimilate more of the mineral matter of their feed than do mature cattle.

Seeding Pastures.—When seeded on arable land, pasture grasses may be sown just as meadow grasses. However, one of the most common ways of seeding pasture grasses is to sow them with a meadow mixture, and after hay has been cut for one or more years, to use the land for pasture. This method is used because some of the best pasture grasses are slow in growth and do not make a complete sod for several years. Etheridge (1919) recommends for Missouri conditions starting a bluegrass

pasture by sowing timothy and bluegrass with wheat in the fall and adding clover in the spring. If this method is followed, the clover and timothy may be cut for hay 2 years and then pastured. As the bluegrass increases in growth the clover and timothy disappear.

Rough, untillable lands sufficiently good to produce pasture grasses may be seeded by sowing suitable seeds on them early in the spring or, preferably, in the late summer. All brush, shrubs and leaves should be either burned or removed from the area to be seeded and the grass mixture seeded without other preparation. The seed should then be disked or harrowed into the soil if the land is clean enough to allow passage of the implement.

Pasture Plants.—Kentucky bluegrass, redtop, white clover and Bermuda grass constitute the five most important pasture plants of the United States. Piper (1915) estimated that when the cultivated pasture plants of America are scaled on the basis of 100, their relative importance is as follows: Kentucky bluegrass, 40; redtop, 10; white clover, 8; Bermuda grass, 8; Timothy, 8; red clover, 4; alfalfa, 4; alsike clover, 3; Canada bluegrass, 3; orchard grass, 2; lespedeza, 2; crab grass, 2; Johnson grass, 2; and all others, 4. The relative values of these plants vary with the section some being suited to certain soil and climatic conditions and others to entirely different conditions. Thus, some of the less important grasses, when the country as a whole is considered, may be the most important grasses for certain sections.

In general, Kentucky bluegrass should be the basis for most permanent pasture mixtures in the North and Bermuda grass the basis for similar mixtures in the South. Piper (1915) recommends the following mixtures for different conditions: (1) Where the soil and the region are adapted to Kentucky bluegrass, add white clover, timothy and either Italian or perennial rye grass. Meadow fescue is also desirable in many places. (2) Where the soil is wet and the region adapted to redtop, add white clover and alsike clover. (3) In the North, where the soil is poor upland, use redtop, Canada bluegrass and white clover. (4) Where Bermuda grass thrives, add lespedeza, white clover, bur clover and Italian rye grass. (5) Where carpet grass predominates, Italian rye grass may prove valuable for temporary pasture in winter. (6) In addition to the grasses mentioned, orchard grass is always desirable, because it furnishes the earliest pasturage; and southward tall oat grass is very useful. On the sandy land along the coast northward, sheep's fescue will often grow to the practical exclusion of other grasses.

Rates of Seeding.—Seedings for pasture are usually in excess of seedings for meadows. Etheridge (1919) recommends seeding the following mixture to the acre on the good lands of Missouri: Kentucky bluegrass, 8 pounds; orchard grass, 5 pounds; timothy, 5 pounds; redtop, 3 pounds; red clover, 2 pounds; alsike and white clover, 1 pound each. On the

poorer land he recommends: orchard grass, 8 pounds; Kentucky bluegrass, 5 pounds; redtop, 4 pounds; red, alsike and white clover, 1 pound each. These mixtures are quite common throughout the grazing section of the central states. In sections where the soils are thin and acid, bluegrass and red clover are not included. A common mixture for thin lands in Virginia is orchard grass, 14 pounds; tall oat grass, 14 pounds; redtop, 5 pounds; and alsike clover 5 pounds.

Hunter and Thompson (19[illegible]) recommend Italian rye grass, 8 pounds; orchard grass, 5 pounds; Kentucky bluegrass, 4 pounds; red clover, 4 pounds; and white clover, 1 pound, for permanent pastures in Oregon and Washington.

Tabor and Crabb (1921), in Georgia, suggest the rates of seeding shown in Table LXXIX for the Coastal Plains area and cut-over pine lands of the South.

Table LXXIX.—Rates of Seeding Pasture Plants in the Coastal Plains Area of the South

Name	When sown alone, lb. per acre	In mixture, lb. per acre
Carpet grass	10	2– 5
Dallas grass	10	2– 5
Bermuda grass	5	2– 3
White clover	5	1– 2
Redtop	10	2– 5
Lespedeza	25	5–15
Orchard grass	14	4–10
Bur clover	6–10 bu.	

Carrying Capacity of Pastures.—No definite statement can be made as to the carrying capacity of pastures. This will depend upon soil, climate and season. The average carrying capacity will vary from 5 to 20 acres per animal unit on the ranges of the Southwest and the cut-over pine lands of the South to less than 1 acre per animal unit on some of the productive bluegrass and white clover pastures of the North. In the bluegrass section of Kentucky it is a common practice to estimate 3 acres of good bluegrass pasture per steer when animals are to be fattened on pasture; and if the pastures are short, 5 to 6 acres of land are often allowed for each fattening steer. When the cattle are not to be finished on pasture, 2 acres of good pasture should be sufficient for an animal unit.

CHAPTER XXIII

MEADOW MANAGEMENT

Meadows as used in this discussion refer to lands devoted to crops which are to be made into hay. Formerly this term was applied only to lands which were too low and wet for the production of cultivated crops, but more recent writers use it for all hay lands wherever found. The plants most commonly used for meadows are the true grasses and clovers. However, many plants of other species are used for hay. All such plants are generally spoken of collectively as "grass," and the lands on which they are grown as "grass-lands."

Duration of Meadows.—Meadows may be permanent or temporary in duration. When the meadows are permanent the lands are seldom or never plowed. Temporary meadows are frequently allowed to remain 1 to 4 years, and usually as a part of the crop rotation.

Value in Rotation.—Meadows consitute the cheapest source of dry forage for live stock and for this reason occupy an important place in the agriculture of the country. In rotations they (1) reduce erosion, (2) form a sod which is favorable to the fixation of nitrogen in the soil and (3) increase the humus supply of soil. All of these functions are extremely important. Probably more nutrients are lost from the soil by erosion than by cropping. When meadows occupy an important place in the rotation, the roots of the grasses hold the soil together and reduce the amount of run-off water. It is a common observation that those sections of our country where grasses do not occupy an important place in agriculture, suffer most from the effects of erosion.

Since some meadows contain clovers or other legumes, they offer a favorable condition for nitrogen fixation; and when the sod is turned under, much organic matter from the roots and crop residues is added to the soil. Farmers generally recognize the soil-improving properties of a sod turned under.

Distribution of Meadow Plants.—Spillman (1907) divides the United States into six divisions based on the type of meadow plants grown. These are: (1) the timothy region, (2) the cotton belt, (3) the Gulf Coast region, (4) the Plains region, (5) the Rocky Mountain states and (6) the Pacific Coast region.

The *timothy region* lies north of the line from Virginia to Kansas and east of a line from Kansas to eastern North Dakota. This is the most important hay section of the United States and produces more hay than

all of the rest of the country. Timothy is the most important meadow plant of the section with red clover as the next important hay producer. Other important hay plants of the section are redtop, alsike clover, orchard grass and meadow fescue. Brome grass, perennial rye grass, Italian rye grass, tall oat grass and alfalfa are grown quite extensively in certain localities within the section but are of secondary importance when the section is taken as a whole.

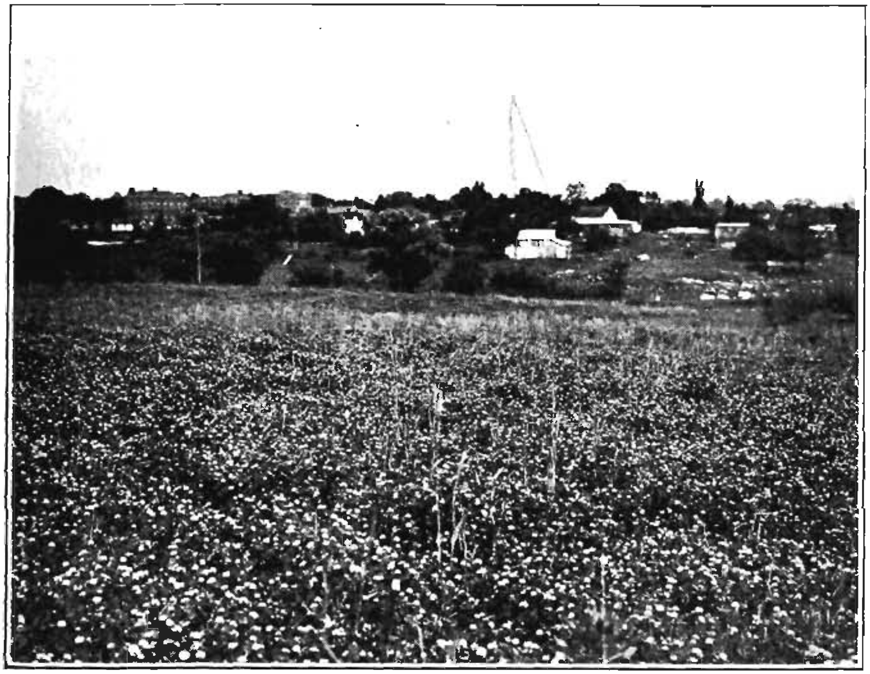

Fig. 30.—An excellent field of alsike clover hay.

The most important hay plants of the *cotton belt* are the annual legumes, such as cowpeas, soybeans, crimson clover, velvet beans and lespedeza. Johnson grass and Bermuda grass are important meadow plants in some localities but are usually avoided in rotation because they are serious weeds in cultivated crops.

In the *Gulf Coast* region crab grass, beggarweed, Mexican clover and velvet beans constitute the most important hay plants. Cowpeas, soybeans and lespedeza are also of importance in certain localities.

Alfalfa, brome grass and the millets are the chief hay plants of the *Plains* region. The grain sorghums are also used extensively for forage purposes.

In the *Rocky Mountain* section alfalfa is by far the most important hay plant. Timothy, clover and orchard grass are grown to a limited

extent in this area and certain wild grasses, such as blue stem and slender wheat, are utilized for hay where they occur naturally.

Alfalfa outranks all other grasses and forage plants in the *Pacific Coast* section. It is almost the only hay crop grown on irrigated lands. On non-irrigated lands the cereals, especially wheat and oats, are used for hay. In the northern part of this section timothy and clover occupy much the same place as they do in the timothy region of the east. Orchard grass and Italian rye grass are also common hay plants.

Methods of Seeding.—There are three principal methods of seeding land to grass: (1) spring seeding with a nurse crop; (2) late summer or early fall seeding without a nurse crop; and (3) seeding in corn or other cultivated crops at the last cultivation.

Spring Seedings.—Spring seeding with a nurse crop is the most common method of seeding rotated meadows. In this method the seeds are sown on small grain fields early in the spring. In case the nurse crop is a fall-seeded grain, the grass and clover seeds are sown as soon as all danger of soil freezing has passed. When the seeds are sown on spring-seeded grain fields, the seeding is done at the time the grain is sown; and on good lands and in seasons when there is an abundance of moisture in the spring and early summer, such seedings grow off well. However, when the soil is thin and the season dry, this method often results in failure to obtain a stand. On the thinner soils the young grass is seriously weakened and sometimes entirely destroyed by exposure to the hot sun when the nurse crop is removed. This method is sometimes modified by sowing the more hardy grasses such as timothy and redtop with the grain in the fall and sowing the clover in the spring. When grass and clover seeds are sown on small grain fields in the spring, they should always be covered. A light smoothing harrow is a good implement to use for this purpose. The harrowing does not injure the grain crop and reduces the chances for a poor stand of grass and clover. Seeds sown on fields without covering catch, if seasonal conditions are right, but often the plants die on account of insufficient moisture.

Late Summer and Fall Seedings.—Late summer and fall seedings usually give splendid results except in sections where protracted droughts commonly occur at these seasons of the year. If clovers are used in the mixture such seedings should be made at least 30 days before the first killing frost date of the section. If no clover is sown, seedings may be delayed for 2 weeks; but even then in most cases the earlier seedings will give better results. In cases where clovers are desired in the mixture and seedings have been delayed, the grasses may be seeded in the fall and the clovers sown early in the spring.

Good soil preparation is essential to success when late summer and early fall seeding is practiced. Either the land should be plowed and subsequently disked and harrowed until a good seedbed is formed, or it

should be disked thoroughly to the depth of at least 3 inches in order to form a finely pulverized seedbed.

Hutcheson (1911) has shown that at the Virginia Experiment Station August seedings of grass were more certain than spring seedings and that they also gave a larger yield of cleaner hay.

Seeding in Cultivated Crops.—Seeding in corn has given good results in many sections where the corn is cultivated level and kept free from weeds. Where this method is followed, the corn should be given a thorough cultivation in order to pulverize the soil before seeding the meadow mixture. The seeds should then be covered by running a fine-toothed cultivator between the rows of corn. This method gives best results on rich soils in sections where rain is abundant in the latter part of the summer.

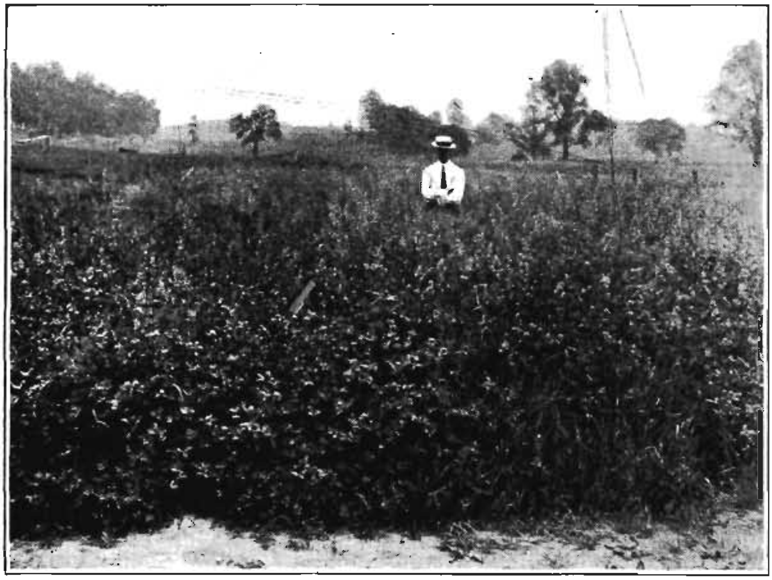

FIG. 31.—A mixture of clover and timothy. A popular hay mixture in the East.

Reseeding Permanent Meadows.—All permanent meadows finally begin to deteriorate and it usually pays to reseed them after they have been down 3 to 5 years Brooks (1910) states that at the Massachusetts Experiment Station a portion of a permanent meadow was plowed and reseeded in the summer. The following year the yield on the portion reseeded was 8,546 pounds of hay to the acre, while that on the plat which was not reseeded was only 6,243 pounds to the acre. Hutcheson (1911) obtained similar results at the Virginia Experiment Station on meadow land which had been down 3 years.

When permanent meadows are to be reseeded, probably the best procedure is to plow the land as soon as possible after the crop is harvested

and work it down by repeated cultivations until time for summer seeding. The seed should then be sown without a nurse crop.

Meadow Mixtures.—Unless hay is grown for a market which demands unmixed hay of a particular variety, it will be found more profitable to sow mixtures of several grasses and clovers than to sow only one kind. The reasons often assigned for this are as follows: (1) The roots of different plants occupy different portions of the soil; (2) mixed hays supply a variety of feed and usually give a better balanced ration than a single kind; (3) most fields are uneven in productivity and other soil conditions and no one plant is particularly adapted to all of the conditions which usually exist in a field; (4) loss by insects or diseases may be lessened; and (5) legumes may aid the growth and increase the protein content of the non-legumes in the mixture.

The data in Table LXXX taken from Piper (1915), show a comparison of single hay plants with mixtures.

TABLE LXXX.—SHOWING HAY YIELDS IN POUNDS TO THE ACRE OF MIXTURES COMPARED WITH BEST SINGLE GRASS

Grass or mixtures	Ill. Exp. Sta., lb.	Ontario Agric. Col., lb.	Kan. Exp. Sta., lb.	Minn. N. E. Exp. Sta., lb.
Timothy	4,400—2 yr.	6,940—7 yr.	4,779—4 yr.	4,340—1 yr.
Red clover	4,200—2 yr.	6,620—6 yr.	5,490—4 yr.	8,000—1 yr.
Tall oat grass	5,480—1 yr.	5,520—7 yr.	1,707—4 yr.	
Alfalfa	....	....	7,345—4 yr.	
Redtop	3,600—1 yr.	3,580—7 yr.	3,399—2 yr.	5,260—1 yr.
Timothy and mammoth clover	5,400—2 yr.			
Timothy and medium red clover	5,200—2 yr.	....	5,490—4 yr.	7,820—1 yr.
Tall oat and alfalfa	....	8,820—2 yr.		
Timothy and alfalfa	....	8,000—2 yr.		
Tall oat and mammoth clover	....	7,160—2 yr.		
Brome grass and red clover	....	....	4,133—4 yr.	
Brome grass and alfalfa	....	....	5,473—4 yr.	
Brome, orchard grass and red clover	....	....	3,825—4 yr.	
Brome grass, timothy and red clover	....	....	3,560—4 yr.	8,480—1 yr.
Brome grass and timothy	....	....	....	5,160—1 yr.
Timothy and redtop	....	....	....	8,740—1 yr.
Timothy and mammoth clover	....	7,140—2 yr.		

In hay mixtures all the grasses used should mature about the same time; otherwise one species will be ready for harvest while the others are still green. Seeding with a miscellaneous mixture of seeds, some of which when seeded alone are of little or no value, is not to be commended. It does not pay to grow in a hay mixture any plants which do not thrive under similar conditions when seeded alone. It is usually best not to put more than three or four varieties of plants in a mixture intended for hay.

Examples of Meadow Mixtures.—A number of mixtures which have given good results in various localities are as follows:

1. The standard mixture for the timothy region is timothy and mammoth red clover. Frequently redtop is added to this mixture; and where mammoth clover fails, it is often replaced by alsike clover.

2. Orchard grass, tall oat grass and alsike clover do well on the thinner soils of the timothy regions.

3. Redtop, alsike clover and meadow fescue are suited to low wet lands.

4. For semi-humid regions, the mixtures recommended are brome grass and timothy or brome grass and orchard grass.

5. Where alfalfa thrives it makes good mixtures with timothy, Johnson grass and tall oat grass.

6. Where Bermuda grass is used for hay, it makes a good mixture with lespedeza.

As a rule the ratio of the amount of seed for different species entering into a meadow mixture will be a little larger than when the plants are seeded alone. For example, when timothy, clover and redtop are seeded alone, 15, 12 and 6 pounds, respectively, would be considered a reasonable rate of seeding. When seeded together, 10 pounds timothy, 8 pounds clover and 4 pounds of redtop, a total of 22 pounds of seed to the acre, would be required.

Fertilizers for Meadows.—The greater part of the hay produced in the United States is grown in rotation; and if fertilizers are used at all, they are usually applied to other crops in the rotation. However, there is an abundance of experimental evidence to indicate that the hay crop responds well to the use of fertilizers and that their use on the hay crop is profitable in sections where the product has a fair market value. Hunt (1910), at the Pennsylvania Experiment Station, states:

> After some years of investigation of this subject I believe it safe to assert that the same money used in applying commercial fertilizers to grass lands will bring a greater profit than when applied for corn or wheat. Of more importance, however, is the fact that while obtaining this greater profit the land is made more productive for succeeding crops. This does not mean that fertilizers may not be used to advantage for either corn or wheat, but merely that a still greater profit results when applied to grass lands.

The data taken from Hunt (1910) show the effect of different fertilizing ingredients on yields of timothy at the Cornell University Agricultural Experiment Station.

Lyon and Morgan (1910) of Cornell University found that where fertilizers were applied to the hay crop which preceded corn, not only did the hay give paying returns from the use of fertilizers but the corn crops which followed gave practically as large yields as when the fertilizers were applied directly to the corn.

Brooks (1910), in Massachusetts recommends fertilizing meadows with a complete fertilizer in which nitrogen predominates. Where clovers

predominate, he recommends reducing the quantity of nitrogen; but for timothy meadows he advises a mixture made up of nitrate of soda 175 to 200 pounds, acid phosphate 50 to 100 pounds and high-grade sulphate of potash 50 to 100 pounds.

TABLE LXXXI.—EFFECTS OF FERTILIZERS ON THE YIELD OF HAY

Kind and amount of fertilizer used per acre	Increase over no fertilizer, lbs. per acre
160 lb. nitrate of soda	1,211
320 lb. acid phosphate	682
80 lb. muriate of potash	988
160 lb. nitrate of soda, 320 lb. acid phosphate	1,614
160 lb. nitrate of soda, 80 lb. muriate of potash	2,082
320 lb. acid phosphate, 80 lb. muriate of potash	1,079
160 lb. nitrate soda, 320 lb. acid phosphate and 80 lb. muriate of potash	2,632
10 tons manure	2,975
20 tons manure	5,175

The hay crop, especially when grown on light sandy soils, responds particularly well to applications of nitrogenous fertilizers. Hutcheson and Wolfe (1919) report that an application of 200 pounds of nitrate of soda on a timothy sod increased the yield from 540 to 1,630 pounds of hay to the acre. This experiment was conducted on a thin, sandy soil of the Coastal Plain section of Virginia.

Cultural Treatment for Meadows.—Cultivation of meadows is sometimes recommended to increase yields; but if timothy and clover are the chief plants in the meadows, cultivation is of a doubtful value. It would probably be better to plow such meadows and reseed.

In the case of alfalfa, early spring cultivation with a spike-tooth harrow or a special implement made for the purpose is recommended. These implements remove some weeds and seem to stimulate the growth of the alfalfa. Meadows consisting of Johnson grass and Bermuda grass have a tendency to become sod bound; and when this is the case, they may be greatly improved by cultivation. The plowing of such fields early in the spring before growth starts greatly increases the yield of hay. In certain cases such meadows may be renewed by putting the land in a cultivated crop for one season. The stand of grasses is not greatly reduced by the cultivation and the breaking up of the sod increases the vigor of the plants.

CHAPTER XXIV

WEEDS

A weed may be defined as "a plant out of place." It follows that a plant may be a weed in some places and not in others. For example, Bermuda grass, which is considered one of the most noxious weeds in places where it is not desired, in certain parts of the South is the most valuable pasture grass. Some plants are considered weeds wherever they grow, as they do not seem to serve a useful purpose anywhere. However, some of our most useful plants have been considered worthless weeds in the past and use may yet be found for many plants that we now consider pests. As late as 1893, laws were passed in Wisconsin to prevent the spread of sweet clover which was classed with Canada thistle as a weed pest.

Loss Due to Weeds.—Weeds cause a direct loss to farmers in the following ways: (1) They lower the selling value of the land; (2) they reduce crop yields; (3) they increase the expense of cultivation and harvest; (4) they reduce the market value of crops; (5) they harbor fungi and insects which attack adjacent crops; and (6) in certain cases they poison or otherwise injure man, live stock or live stock products.

Reduction in Selling Value.—Lands overgrown with weeds of certain kinds practically always sell for a lower price per acre than similar lands which are free from these pests. In certain sections lands have been greatly reduced in price by invasion of such weeds as quack grass, Johnson grass and Canada thistle. Because of the increased difficulty of cultivation, such lands are not worth as much as weed-free land and should therefore justly sell for a lower price.

Reduction in Yield.—Examples of reduced yields due to weeds are common. All plants require a certain amount of nutrients, water and space for growth; and when crowded, they cannot thrive. If the space needed for their development is to any extent occupied by weeds which rob the cultivated plants of nutrients, moisture and sunlight, the returns from the crop must be correspondingly less.

Hutcheson, Hodgson and Wolfe (1917) allowed weeds to grow in one plat of corn and on an adjacent plat they kept all weeds cut close to the surface of the ground. In each case the soil was not stirred after the corn was planted. As the result of a 4 years' test the plat on which the weeds were allowed to grow gave an annual yield of 8.17 bushels of corn to the acre, while that from which the weeds were removed gave

an average yield of 49.04 bushels to the acre. This result means a loss of 40.87 bushels of corn to the acre due entirely to the presence of weeds. In this experiment no weeds were removed; but even when only a few weeds are left in cultivated crops, the yield is correspondingly reduced.

Increased Cost of Cultivation and Harvest.—The presence of weeds not only decreases yields but also increases the expense of cultivation and harvest. A corn or cotton field infested with Johnson grass or Bermuda grass requires almost twice as much cultivation to insure a profitable crop as does a field comparatively free from persistent weeds. A field infested with weeds such as cockle, dock or thistle requires extra horse labor and causes extra depreciation of machinery in harvest. Also the labor for threshing and cleaning the seed from a weedy crop is much greater than for a clean crop.

FIG. 32.—Wild garlic, one of the serious weeds in grain fields. From left to right: aërial bulblets (above) and wheat kernels, hard-shelled bulbs and soft-shelled bulbs attached to stem.

Reduction in Market Value.—The market value of crops is always greatly reduced by the presence of weeds. The dockage of grain due to weed seeds is a constant source of loss to farmers. Hay containing large quantities of weeds brings very low prices on the market and in most cases is greatly reduced in feeding value. Crops intended for seed suffer a great reduction in price when they contain weed seeds, for such crop seeds must go through an expensive operation of cleaning before they can be marketed or they must be sold as low-grade seeds. Georgia (1914) says:

> A report from the Grains Inspection Department of the state of Minnesota shows the average dockage of wheat for two years to be nineteen ounces to the bushel. Minnesota produces yearly more than two hundred million bushels of small grain. A dockage of but one pound to the bushel means a loss of over two hundred million pounds, and if the money value be calculated at no more than a cent a pound it is two million dollars yearly; and this loss is in addition to decrease of yield and increased cost of harvest.

Harboring of Pests.—It is a well-known fact that certain weeds act as host plants for important diseases and insects. Examples of these are club root in cabbage, which is fostered on wild members of the mustard family; southern tomato wilt, which will live on ragweed and other succulent plants; septoria leaf spot of tomatoes, which is fostered by horse

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Harboring of Pests.—It is a well-known fact that certain weeds act as host plants for important diseases and insects. Examples of these are club root in cabbage, which is fostered on wild members of the mustard family; southern tomato wilt, which will live on ragweed and other succulent plants; septoria leaf spot of tomatoes, which is fostered by horse

nettle; and the Colorado potato beetle, which also lives on some of the other members of the nightshade family.

Some Other Effects of Weeds.—Certain weeds like poison ivy, jimson weed and seeds of corn cockle are injurious to man. Others, such as larkspur, water hemlock and loco weed, are poisonous to live stock and

FIG. 33.—Hawkweed, a serious pasture pest.

cause considerable loss to stockmen. Wild garlic and bitter weed reduce the price of dairy products by giving them an unpleasant taste.

When to the foregoing is added the loss of pasturage due to the invasion of such weeds as hawkweed, Canada thistle and sneezeweed, it is readily seen that the damage each year due to weeds in the United States is very great.

Advantages of Weeds.—Weeds are not always useless. Often they are the principal means by which organic matter is added to the soil.

Ince (1915) at the North Dakota Experiment Station has shown that weeds contain a large amount of mineral nutrients. When they are returned to the soil, these nutrients become available for more useful plants. They take up soluble plant nutrients on land which is not in cultivated crops and prevent the leaching of these nutrients from the soil. They also afford a covering for waste places and thereby check erosion by water and winds. Weeds may serve another useful purpose because they compel the cultivation of the soil.

However, all of these benefits may be obtained where proper rotation is possible, in which case it is not usually economical to permit weed growth.

Classification of Weeds.—The habits of life, growth and propagation of weeds determine the methods of their control. Weeds may be classified into three groups according to their duration or length of life: (1) annuals, (2) biennials and (3) perennials.

Annual Weeds.—Annual weeds are of two kinds, *summer annuals* and *winter annuals.* Summer annuals grow from seed each spring or summer and do not survive the winter. Winter annuals germinate in summer or autumn, live over winter and mature and die the next year. The annual weeds depend for propagation upon the seeds they produce. Most of the ordinary annual weeds, if well developed, produce from 10,000 to 1,000,000 seeds per plant. These seeds do not all germinate at the same time but some of them remain viable in the soil for years and come up when conditions become favorable. Arthur (1915) reports as the results of experiments carried on at the Indiana Experiment Station, that from 127 to 489 viable seeds were found to the square foot of field soil 6 inches deep. The smaller number was found in well-cultivated fields and the larger number in fields where weed eradication had been neglected. Annual weeds are comparatively easy to control by cultivation, and, if prevented from seeding, have no means of reappearing except from old seeds in the soil.

Biennial Weeds.—Biennial weeds live 2 years. During the first year they grow rather slowly, producing usually a tap root and a rosette of leaves close to the ground; during the second year they send up flowering stems that produce seeds and then die. Such weeds are eradicated by the prevention of seeding and by the destruction of the rosettes which appear in the fall.

Perennial Weeds.—Perennial weeds live over winter from year to year either above or below ground. The underground parts besides roots may consist of underground stems, rootstocks or bulbs. These perennial weeds are often very difficult to eradicate, as when the top is killed the underground parts contain a supply of food material for renewing growth.

In Table LXXXII, taken from Cox (1915), is given a description of 50 of the worst weeds of the United States.

Table LXXXII.—Descriptive List of Fifty of the Worst Weeds of the United States
(A = annual, B = biennial, P = perennial)

Common name, botanical name and duration of life	Color, size and arrangement of flowers	Sections where injurious	Method of seed distribution; vegetative propagation of the perennials	Place of growth and products injured
Bermuda grass (*Capriola dactylon*), P.	Purple; 1/12 in.; spikes.	Maryland to Missouri and southward.	Seeds sparingly; rootstocks.	Fields and lawns; hoed crops.
Bindweed, field bindweed (*Convolvulus arvensis*), P.	White or pink; 1 in.; solitary.	Entire United States, especially California.	Grain and flax seeds; creeping roots.	Rich, moist soils; grain and hoed crops.
Bindweed, hedge bindweed (*Convolvulus sepium*), P.	White or rose; 2 in.; solitary.	Mississippi Valley region.	Grain and flax seeds; rootstocks.	Rich prairie and river bottoms; corn and small grain.
Bitterweed, yellow dogfennel (*Helenium tenuifolium*), A.	Yellow; 3/4 in.; head.	Virginia to Kansas and southward.	Wind, hay, animals.	Meadows and pastures; injures live stock and taints milk.
Brake (*Pteridium aquilinum*), P.	No flowers.	Northwestern states and the Pacific Coast.	Spores scattered by wind; running roots.	Logged-off land, meadows and pastures.
Broom-sedge (*Andropogon virginicus*), P.	Green; 1/4 in.; racemes.	Massachusetts to Michigan, Florida and Texas.	Wind; short root stocks, plants in tufts.	Fields and waste lands; pastures and meadows.
Buffalo bur (*Solanum rostratum*), A.	Yellow; 1/2 in. solitary.	Illinois and Colorado to Texas.	Plants rolled by wind; seeds in hay and by animals.	Fields; grain and hoed crops, wool.
Chess, cheat (*Bromus secalinus*), A.	Green; spikelets in panicles.	All grain sections.	Grain seed; especially wheat.	Everywhere; grain fields.
Chickweed, common chickweed (*Alsine media*), A.	White; 1/8 in.; cymes.	Entire United States.	Grass and clover seed, animals; has a long seeding period.	Meadows, lawns; winter crops.
Cocklebur, clotbur (*Xanthium americanum*), A.	Green; 1/4 in.; head.	Entire United States.	Carried by animals.	Cultivated fields and waste places; hoed crops and wool.
Crabgrass (*Syntherisma sanguinale*), A.	Green; spikes.	Entire United States, especially the South.	Clover and grass seed, hay, animals.	Cultivated fields, gardens, lawns, hoed crops.
Daisy, oxeye daisy (*Chrysanthemum leucanthemum*), P.	White with yellow center; 1 in.; heads.	Maine to Virginia and Kentucky.	Clover seed, hay; woody, rather short rootstocks, but largely by seed.	Pastures, meadows, roadsides; hay, pasturage.
Dandelion (*Leontodon taraxacum*), P.	Yellow; 1 1/4 in.; head.	Entire United States.	Wind; taproot, which spreads but little.	Lawns, meadows, waste places; hay and lawns.
Dock, yellow dock (*Rumex crispus*), P.	Green; 1/4 in.; panicle.	Entire United States.	Hay and straw, clover and grass seed; taproot, which spreads but little.	Hay, small grain and hoed crops.
Dodder, alfalfa dodder, field dodder (*Cuscuta arvensis*), A.	Yellow; 1/8 in.; clusters.	All clover and alfalfa regions.	Hay, clover and alfalfa seed.	Clover and alfalfa fields.
Dogbane, Indian-hemp (*Apocynum cannabinum*), P.	Greenish white; 1/4 inch; terminal clusters.	Upper Mississippi Valley.	Wind; creeping root.	Fields with sandy soil; pasture, grain and hoed crops.
Foxtail, yellow foxtail, pigeon grass (*Chaetochloa lutescens*), A.	Green; spikes.	Upper Mississippi Valley.	Animals, hay, grain and grass seeds.	Land cultivated in early part of season; young grass and clover seedlings.
Hawkweed, orange hawkweed, devil's-paintbrush (*Hieracium aurantiacum*), P.	Orange; 1 in.; heads.	Maine to Ohio.	Wind, grass and clover seeds; runners similar to strawberry.	Untillable pastures and meadows.

TABLE LXXXII.—*Continued*

Common name, botanical named and duration of life	Color, size and arrangement of flowers	Sections where injurious	Method of seed distribution; vegetative propagation of the perennials	Place of growth and products injured
Horsenettle (*Solanum carolinense*), P.	Purple; 1 in.; solitary.	Entire United States.	Plants rolled by wind; running roots.	Everywhere; grain and hoed crops, pastures.
Horseweed (*Erigeron canadensis*), A.	White; 1/4 in.; heads in cymes.	Entire United States.	Hay, grass and clover seeds.	Meadows, pastures and grain fields.
Ironweed (*Vernonia noveboracensis*), P.	Purple; 1/8 in.; heads.	Maine to Maryland and Iowa to Kansas.	Wind; short thick rootstocks, making plant grow in bunches.	Pastures and meadows.
Jimson weed (*Datura stramonium*), A.	Purple; 3 in.; solitary.	Maine to Minnesota and Texas.	Pods and plants blown by wind.	Pastures, barnyards and waste lands; seeds, flowers and leaves poisonous.
Johnson grass (*Holcus halepensis*), P.	Green; 1/8 in.; panicle.	Virginia to Texas and California.	In hay, grain and grass seed; running rootstocks.	All crops except hay.
Lamb's-quarters (*Chenopodium album*), A.	Green; very small; panicle.	Entire United States.	Grain and grass seed.	Grain fields and hoed crops.
Lettuce, prickly lettuce (*Lactuca scariola*), A.	Yellow; 1/4 in.; heads in panicles.	Ohio to Iowa, Utah to California.	Wind.	Everywhere; all crops.
Milkweed, common milkweed (*Asclepias syriaca*), P.	Purple; 1/2 in.; umbels.	New York to Minnesota.	Wind; creeping roots.	All crops and in pastures.
Morning-glory (*Ipomoea hederacea*), A.	White, purple, or blue; 1 1/2 in.; solitary.	New York to Missouri.	Corn stover, straw and wind.	Cultivated fields, especially corn and small grain.
Mustard, wild mustard, charlock (*Brassica arvensis*), A.	Yellow; 1/2 in.; racemes.	Maine to Washington.	Grain, grass, clover and rape seeds.	Small-grain fields and meadows; grains.
Nutgrass, coco (*Cyperus rotundus*), P.	Brown; 1/16 in.; spikelets.	Maryland to Florida and Texas.	Wind, nursery stock, hay and grass seed; tubers.	All soils; hoed crops.
Pennycress, Frenchweed (*Thlaspi arvense*), A.	White; 1/8 in.; racemes.	North Dakota and Minnesota.	Wind.	Grain fields and pastures; grain and diary products.
Pigweed, redroot, careless weed (*Amaranthus retroflexus*), A.	Green; very small; spikes in panicles.	Entire United State.	In grain and grass seeds; plants blown by wind.	Plowed land; hoed crops.
Plantain, buckhorn, ribgrass (*Plantago lanceolata*), P.	White; 1/16 in.; spike.	Entire United states.	Hay, clover and grass seed; spreads but slowly from a crown.	Everywhere; meadows, pastures and lawns.
Poison ivy (*Rhus toxicodendron*), P.	Greenish white; 1/8 in.; panicles.	Entire United States.	Does not spread fast by seeds; running rootstocks.	Moist rich land, along fences; poisonous by contact.
Purslane, pusley (*Portulaca oleracea*), A.	Yellow; 1/4 in.; solitary.	Entire United States.	Tillage implements; has a long seeding period.	Rich cultivated land, especially gardens; hoed crops.
Quackgrass, witchgrass (*Agropyron repens*), P.	Green; spike.	Maine to Pennsylvania and Minnesota	Seeds of grain and coarse grasses; creeping rootstocks.	All crops on the better soils; hoed crops.
Ragweed, smaller ragweed (*Ambrosia elatior*), A.	Yellow; 1/4 in.; small heads on spikes.	Entire United States.	Wind carrying matured plants; in grain and red-clover seeds.	Everywhere, especially grain stubble; hoed crops and young grass seeding.
Russian thistle (*Salsola pestifer*), A.	Purplish; 1/4 in.; solitary.	Minnesota to Washington and southward.	Wind rolling matured plants.	Everywhere; small grain and hoed crops.
St.-John's-wort (*Hypericum perforatum*), P.	Yellow; 3/4 in.; cymes.	Maine to North Carolina and Iowa.	In hay and grass seed; rootstocks.	Meadows, pastures and waste places.
Sandbur (*Cenchrus carolinianus*), A.	Green; 1/8 in.; bur.	Maine to Florida and westward to Colorado.	Animals, especially sheep.	Sandy land pastures and waste places; pastures and wool.

TABLE LXXXII.—*Continued*

Common name, botanical name and duration of life	Color, size and arrangement of flowers	Sections where injurious	Method of seed distribution; vegetative propagation of the perennials	Place of growth and products injured
Smartweed (*Polygonum pennsylvanicum*), A.	Light rose; 1/16 in.; racemes.	Maine to Minnesota, Florida and Texas.	Wind carrying matured plants.	Moist, rich soils, hoed crops and young grass seedings.
Smartweed, marsh smartweed, devil's-shoestring (*Polygonum muhlenbergii*), A.	Rose color; 1/16 in.; spikes.	Indiana to Iowa.	Wind and farm machinery; rootstocks.	Wet land, prairie, and muck soils; hoed crops, hay, pasture.
Sorrel, sheep sorrel (*Rumex acetosella*), P.	Red; 1/8 in.; panicles.	Entire United States.	In clover seed; creeping roots.	Meadows and pastures.
Sowthistle, perennial sowthistle (*Sonchus arvensis*), P.	Yellow; 3/4 in.; heads.	Maine to Minnesota.	Wind; running rootstocks.	Grain fields and hoed crops.
Squirreltail grass, squirrel grass, foxtail, wild barley (*Hordeum jubatum*), A.	Green; spike with long bristly glumes.	Minnesota to Texas and California.	Hay, animals, wind.	Meadows and pastures; barbed seeds produce sores on live stock.
Thistle, Canada thistle (*Cirsium arvense*), P.	Purple; 3/4 in.; heads.	Maine to Pennsylvania and Washington.	Wind, in hay and straw and in clover and grass seed; creeping roots.	All crops.
Thistle, common thistle, bull thistle (*Cirsium lanceolatum*), B.	Reddish purple; 1 in.; heads.	Maine to Virginia and Washington.	Wind, in alfalfa, clover and grass seeds.	Pastures, meadows and winter wheat.
Wild carrot (*Daucus carota*), B.	White; very small; umbels.	Maine and Virginia to the Mississippi.	In foreign clover and alfalfa seed; carried by animals and wind.	Meadows and pastures.
Wild oats (*Avena fatua*), A.	Green; panicles; similar to oats.	Wisconsin to Washington.	In seed oats.	Oat fields; awns injurious to stock.
Wild onion, garlic (*Allium vineale*), P.	Flowers rare; umbels with bulblets.	Rhode Island to Georgia and west to Missouri.	Seeds rare; bulblets carried in wheat; underground bulbs.	Everywhere; wheat and dairy products.
Wintercress, yellowrocket (*Campe barbarea*), P.	Yellow; 1/4 in.; racemes.	Maine to Virginia and westward.	In grain, clover and grass seeds.	Grain fields, pastures and meadows

Classification According to Habitat.—Weeds may also be classified according to habitat as follows: (1) weeds of cultivated fields, (2) grain weeds, (3) grass land weeds, (4) garden weeds, (5) orchard weeds, (6) lawn weeds and (7) waste land weeds. In cultivated fields and gardens the ordinary operations of cultivation are the main dependence for weed control. In grain and grass lands one must depend upon clean seeds and clean cultiva'ion of previous crops. In pastures, mowing, sheep grazing and spraying small patches of weeds give good results. The weeds of waste lands may be kept under control by mowing and burning. Weeds common to wet lands disappear when the land is drained.

Dissemination of Weeds.—Weed seeds are scattered by many agencies. The most common agencies of dispersal are wind, water, animals, wool, cultivation, impure seeds, highways and peculiar mechanism of the plant itself.

Many weed seeds are light and easily blown about by the wind; others are equipped with feathery tufts, such as those of dandelions and milkweeds, which enable them to be carried through the air from place to place. A number of very troublesome weeds, such as cockleburs

and docks, are carried by water. The seeds of these weeds are washed down to streams by heavy rains and are deposited when these streams overflow.

Wool is responsible for the spread of many weeds. The seeds of some weeds easily catch in the wool when sheep are feeding and are carried

FIG. 34.—A weedy hay field. The seeds of most of these weeds were sown with the grass seeds.

by them to other localities. Many foreign weeds have been brought into this country in uncleaned wool and have spread from the vicinity of woolen mills.

It is not uncommon for weeds to be carried from place to place by plows and cultivators; Bermuda grass and quack grass are often spread in this manner.

Animals and birds eat the seeds of numerous weeds. These often pass through the digestive system with their vitality unimpaired and are scattered in droppings. Other weed seeds are carried from place to place in the coats of animals.

Highways are an important factor in the distribution of weeds to adjacent fields. Weeds are usually allowed to grow uninterrupted along the roadside, and the seeds so produced are carried by the usual agencies to adjacent fields.

Certain weeds are equipped with peculiar mechanisms which aid in scattering their seeds. Certain species of oxalis have explosive prop-

erties which scatter their seeds to considerable distances. Many seeds of leguminous plants are thrown out violently by the twisting action of the bursting pod; other weed seeds, like stick weed, Spanish needles and cocklebur, have a mechanism for attaching themselves to passing objects and are thus carried from place to place.

Control of Weeds.—There are four general methods of weed control: (1) cultivation, (2) smothering, (3) chemical sprays and (4) the use of clean seeds.

Cultivation.—The processes of tillage, by destroying weeds with the hoe, plow or cultivator, not only kill the living weeds but when done at the proper time prevent the seeds from maturing. Then too, tillage, by stirring the soil, brings deeply buried seeds close to the surface and induces germination after which succeeding cultivations may kill them. In this manner many weeds may be destroyed in one season.

In some cases weeds may be destroyed by cultivating or harrowing meadow land. This practice is common in some sections, particularly for alfalfa meadows. However, when grasses with creeping rootstocks, such as Bermuda grass, Johnson grass and quack grass, constitute the meadow weeds, this practice is not advisable, as harrowing merely breaks the rootstocks of these pests and growth is invigorated.

Bare summer fallow is sometimes practiced for cleaning old weed fields. When this method is followed, the land should be plowed in the early summer and disked or harrowed often enough during the summer to induce germination of the weed seeds and to kill all the plants which come up. The same end can be accomplished in most cases by planting the land to a cultivated crop, in which case clean culture is required.

Cultivation to be efficient in weed eradication must be thorough and must be kept up late enough to prevent the maturing of all seeds before frost.

Smothering.—The growing of a heavy, dense cover of some crop such as buckwheat, cowpeas or soybeans that will outgrow the weeds and deprive them of light, water and plant nutrients is another method of destroying persistent weeds. This is perhaps the best method of destroying Bermuda grass. This plant is very persistent in cultivated fields but it may be smothered out by keeping the land well covered with dense-growing crops for two or more years. Cocke (1919) found that, under eastern Virginia conditions, Bermuda grass and other weeds were effectively eradicated from alfalfa fields by the use of manure and commercial fertilizers in sufficient quantities to induce rapid growth of the alfalfa.

Chemical Sprays.—Chemical herbicides are now used quite extensively in fighting weeds. The most common of these materials are common salt (sodium chloride), copperas (iron sulphate), bluestone (copper sulphate), carbolic acid (phenol), oil of vitrol (sulphuric acid), corrosive sublimate

(bichloride of mercury), kerosene oil and arsenite of soda. Most of these materials are limited in usefulness on account of their cost or danger in use. Some of them, such as carbolic and sulphuric acids are unpleasant to handle, as they cause painful burns when they come in contact with the body; others, such as corrosive sublimate and arsenite of soda, are deadly poisons and cannot be used where live stock have access to the treated field.

Common salt is one of the cheapest and safest of herbicides, but is not the most useful, since where used in large enough quantities to kill certain weeds, it permeates the soil to such an extent that all growth is checked for a season. If this material is used, it should be applied in the late summer so that the harmful effect will have time to disappear, partially at least, before the following spring.

Kerosene, carbolic acid and caustic soda are well suited to destroying small areas of persistent weeds. However, these materials completely sterilize the soil for a time and cannot be used for killing weeds in growing crops.

Iron sulphate and copper sulphate are the best known herbicides for use as weed killers in growing crops. Grains and grasses are very resistant to injury from these materials, while some of the common grain weeds are easily killed by them. Of these two materials, iron sulphate is probably best for general use as it is cheaper and somewhat more effective on older weeds.

Iron Sulphate for Weed Eradication.—When iron sulphate is used as a spray a solution of about 100 pounds of iron sulphate to 50 gallons of water should be employed. This amount should be sufficient to spray about an acre of herbage. It is necessary that the spray shall be a fine mist, as large drops roll off the leaves of the plant. A high-pressure spray pump is necessary to bring about this condition and the solution should be applied, for best results, before the grain begins to head and when the weeds are young and tender.

The data in Table LXXXIII from Norton (1911) give the effect of iron sulphate on some of the useful plants and on the most common weeds.

Clean Seeds.—The question of clean seeds is a very important one in weed control. Nearly all of our bad weeds have been introduced in seeds of various crops, especially in grass and clover seeds. Constant vigilance should be maintained and no seeds should be sown without careful examination for weed seeds. Those who purchase seeds for sowing should familiarize themselves with all of the more noxious weed seeds and should refuse to purchase any seeds in which they are contained.

TABLE LXXXIII.—EFFECT OF IRON SULPHATE SPRAY ON CERTAIN PLANTS

Injury slight or none	Usually killed	Young plants killed	Injured but not killed
Alfalfa	Mustard	Stick tight	Beets
Beans	Sweet clover	Spanish needle	Cucumber
Celery	Buttercup	Dock	Cowpea
Crimson clover	Cocklebur	Jimson weed	Melons
Grasses and grains	Oxeye daisy	Ragweed	Red clover
Wild carrot	Charlock	Ripple weed	Dog fennel
Burdock	Pepper grass	Cinquefoil	Tumbling mustard
Lamb's-quarter	Pigweed		Sorrel
Couch grass	Mosses		Dandelion
Yarrow	Buttonweed		White-top
Morning-glory	Yellow oxalis		Plantain
St. John's-wort	Carpet weed		Thistles
	Corn chamomile		

CHAPTER XXV

CROP ROTATION

Crop rotation may be defined as a more or less regular recurrent succession of different crops on the same land. It differs from a haphazard change of crops from time to time, in that it contemplates the growing of a group of crops in regular succession through a considerable period of years according to a definite plan. Rotations may be of any length, but owing to the limited number of crops usually profitable in a given section, they are most commonly of 3 to 7 years' duration.

Reasons for Crop Rotations.—There are many benefits, both direct and indirect, to be obtained from a good rotation. Crop rotation (1) helps to control weeds, insects and diseases; (2) may aid in maintaining the supply of organic matter in the soil; (3) may aid in the maintenance of the soil nitrogen supply; (4) often saves labor; (5) keeps the land occupied a greater part of the time with crops; (6) allows for crop alternation; (7) regulates the use of plant nutrients from the soil; (8) systematizes farming; and (9) increases crop yields.

Control of Pests.—With each crop appear certain typical weeds which are much less serious in other crops. For example, pigweed, lamb's-quarter, cocklebur and foxtail are typical weeds of corn fields. With small grains, ragweed, wild mustard, cockle, wild onion and thistles may abound. Common weeds which occur in hay fields are oxeye daisy, plantain, sheep sorrel and wild carrot. These weeds increase rapidly if a crop is grown continuously, but can be frequently subdued by a change of crops. Many insects trouble only one plant or one group of plants. The Hessian fly, for example, does little damage except in wheat fields, and if the wheat crop is grown continuously, the Hessian fly may increase rapidly. Changing crops is an effective method of checking the damage from insects. Sometimes it is necessary to omit the crop entirely for a few years, but usually a rotation of proper length will bring these pests within the limits of economic control.

Similarly, there are many diseases that injure one crop but are not harmful to other crops. Potato scab may become serious if the potato crop is grown on the land year after year, and smuts of grain may increase rapidly under continuous cropping to grain plants. Nearly all of the plant diseases are checked to some extent and many of them are controlled by a proper rotation.

Maintenance of Organic Matter.—If lands are kept constantly in tilled crops, the supply of organic matter is seriously decreased. Small

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grain crops bring the same results but less rapidly. Grasses and clovers usually increase the supply of organic matter.

Nitrogen Supply.—Clovers and legumes generally may not only increase the supply of organic matter but help to maintain the nitrogen supply of the soil. No single cropping system will ordinarily maintain the nitrogen supply of the soil unless leguminous cover crops are alternated with the other crops.

Economy of Labor.—Crop rotation often makes it possible to grow two or more crops with one soil preparation or after one plowing. Thus, in some sections where a rotation of corn, wheat, clover and grass is practiced, the land is plowed for corn, the corn stubble is disked for wheat and the grass and clover are seeded in the wheat without further preparation. If corn were grown continuously in these sections, the land would have to be plowed and prepared four times in the same period. The saving of labor and time made possible by the elimination of plowing and other preparation increases the area one man can handle and reduces the cost of producing an acre of crops.

Protection of the Soil.—It was once believed necessary to leave land idle for a part of the time in order to maintain productivity. Now it is known that a proper rotation of crops with due attention to essential plant nutrients will bring the same results much more economically. The land represents the farmer's bank account and all parts of it should return yearly interest. In sections where the rainfall is heavy and where climatic conditions make plant nutrients available, much loss will occur through leaching unless growing plants are present to take up these soluble materials. It follows that some system of cropping which will keep the ground covered will conserve more plant nutrients than is possible where the soil lies bare a portion of the year.

Alternation of Corps.—Rotation may provide for the alternation of deep- and shallow-rooted crops and thus allow for a more complete use of the soil. Potatoes, tobacco and small grains are shallow-rooted crops. If such crops are used exclusively, only the surface soil is utilized. On the other hand corn, clover and alfalfa are deep-rooted crops, and where alternated with the first-mentioned group, utilize the soil more completely.

A Balanced Removal of Plant Nutrients from the Soil Allowed.—Plants use nutrients from the soil in different proportions; and when properly alternated, they may reduce the different nutrient materials of the soil in a more desirable proportion. If, however, a single crop which feeds heavily on one group of materials is used continuously, this group may be greatly reduced, while another group of materials which might be used in large proportions by other crops is used only sparingly. Alternation of crops is desirable in order that all available nutrients may be used by crops and loss from leaching may thus he reduced.

However, it should be remembered that the larger crop yields obtained from rotations result in a greater total removal of plant nutrients than is the case when single crops are grown. Therefore, rotation alone is not sufficient to maintain productivity.

Farming Systematized.—Crop rotation allows a more complete year's work with few periods of idleness, and by distributing the risks among several crops helps to prevent complete failure. Usually a cropping system simplifies the farm layout and reduces the number of fields on the farm. It also enables one to estimate ahead of time the amount of labor, the quantity of seed and the power and machinery necessary for the operation of the farm and does away with extreme rush work which is so common when haphazard cropping is practiced.

Increase of Crop Yields.—Rotation of crops usually increases crop yields. However, if yields were not increased, rotation of crops would be desirable as a means of reducing the cost of production.

Hopkins, Readhimer and Eckhardt (1908) in Illinois, compared continuous corn cropping with an alternation of corn and oats and a corn, oat and clover rotation. The comparisons are based on the acre yields for the last 3 years during which each area was planted to corn, and the results are shown in Table LXXXIV.

TABLE LXXXIV.—ROTATION AS COMPARED WITH CONTINUOUS CROPPING AT THE ILLINOIS EXPERIMENT STATION SHOWING LATEST YIELDS OF CORN (3-YEAR AVERAGE)

Crop years	Crop system	13-yr. experiments, bu.	29-yr. experiments, bu.
1905–6–7	Corn every year..........	35	27
1903–5–7	Corn and oats............	62	46
1901–4–7	Corn, oats and clover.....	66	58

Stevenson and Brown (1916) report the results of rotations shown in Table LXXXV for Iowa conditions.

Arny (1917) reports that at the Minnesota Experiment Station in a 4-year rotation of oats, wheat, clover hay and corn, the increase in net income per acre as compared with the income obtained from growing the same crops continuously: was corn, 29.2 per cent; oats, 35.2 per cent; and wheat, 72.3 per cent. These are the results of an experiment which had continued over a 6-year period.

Wiancko and Fisher (1906), in Indiana, report, as shown in Table LXXXVI, the wheat yields for the year 1906 on plats which had been in different rotations for 18 years.

TABLE LXXXV.—AVERAGE YIELDS OF CROPS IN VARIOUS ROTATIONS FOR 6 YEARS (1908–1913) IN IOWA

Treatment	Corn, bu.	Oats, bu.	Clover, tons
Continuous corn	40.32		
2-yr. rotation, corn and oats	55.75	51.51	
3-yr. rotation, corn, oats and clover	64.25	65.14	2.97
2-yr. rotation, corn and oats, clover turned under	66.55	54.58	
2-yr. rotation, corn and oats, cowpeas turned under	55.18	54.81	
2-yr. rotation, corn and oats, rye turned under	54.59	55.38	
Continuous clover	.....	.....	1.69

Many other examples could be given to show the increased yields obtained by rotations. The increases are usually particularly striking where clover is included in the rotation.

TABLE LXXXVI.—SHOWING EFFECTS OF ROTATION UPON YIELDS OF WHEAT

Rotation	Wheat yields, bu. per acre
Corn, wheat (not plowed for wheat)	16.5
Corn, oats, wheat	22.0
Wheat	22.7
Corn, oats, wheat, clover and grass	25.6
Corn, oats, wheat, clover	29.1
Corn, oats, wheat and cover	25.2

Essentials of a Good Rotation.—The characteristics of a good cropping system, according to Warren (1913), are as follows:

1. The area of each crop should be nearly the same year after year unless there is a definite reason for changing it.
2. The rotation should provide roughage and pasture for the animals kept.
3. The rotation should include one tilled crop for the elimination of weeds.
4. It is desirable that a rotation include a sod.
5. The rotation and feeding system should provide for keeping up the organic matter of the soil.
6. The rotation should provide as large an area of the most profitable cash crop or crops as can be cared for.

Planning the Rotation.—After the characteristics of a good cropping rotation have been determined, the next problem is to select the best adapted crops. A crop should be grown not just because it will pay, but because it will pay best in the particular type of farming followed.

The proper sequence of crops is also an important consideration. In general, the most profitable crop should be given the best place in the rotation. Attention should also be given to the labor requirements as influenced by the sequence. In sections where grain and grass are grown, a cultivated crop is usually followed by a small grain crop and this in turn is followed by grasses and clovers. Such a sequence minimizes the labor of soil preparation and at the same time brings each crop where it is likely to do best in the rotation. The kind of soil has an important influence on the kind of crops to grow in a rotation; and when there are two types of soil on the same farm, it may be advisable to have two rotations. In the bright tobacco sections of the South it is usually advisable to have one rotation for tobacco and another for the production of food and feed. This practice is best because it is practically impossible to produce bright tobacco of high quality on soils which have been built up to a high state of productivity by the use of legumes and from the use of farmyard manure.

Duration of Rotations.—The duration of a rotation is governed somewhat by the type of farming. In trucking sections where the most salable products are usually cultivated crops, the rotations are commonly of short duration. Where hay is the chief cash crop, longer rotations are practiced, and in such sections 6- or 7-year rotations are not uncommon. Probably the most common rotations of the United States are of 3 or 4 years' duration; in these rotations a cultivated crop is followed first by a small grain crop and then by grass or clover. The grass and clover crops remain for 1 or 2 years.

Examples of Good Rotations.—Obviously it would be impossible to give rotations which would be useful in all sections. A few type rotations taken from bulletins from different localities follow. These may be modified to suit local conditions if the characteristics of a good rotation are kept in mind.

Burdick (1915) recommends the following rotations for Vermont:

Corn, oats, clover and timothy 3 years.
Corn, oats, clover.
Corn, oats, barley, hay 2 or 3 years.
Oats, barley, hay as long as the hay will grow.
Potatoes, oats, clover.
Beans, oats, clover.

Delwiche (1912) gives several rotations for Wisconsin and some of those recommended are:

Corn or cultivated crop, small grain, clover.
Cultivated crop, small grain, clover and grass 2 years.
Peas, small grain, mixed clover and timothy 2 years.
Peas, small grain, clover, cultivated crop.
Cultivated crop, small grain, alfalfa 3 years.
Cultivated crop, small grain, mixed clover and timothy 2 years, peas.

Wysor (1922) advises the following rotation for various sections of Virginia and states that wherever corn is written, other cultivated crops may be inserted; and that wherever wheat is wr'tten, other small grains may be substituted;

Corn, wheat, clover.
Corn, wheat, clover and grass 2 years.
Corn and crimson clover, soybeans or cowpeas, wheat, clover.
Corn and cowpeas, wheat, clover and grass 2 years.
Dark tobacco, wheat, clover.
Dark tobacco, wheat, clover and grass 2 years.
Bright tobacco, wheat, redtop.
Peanuts, soybeans and crimson clover, corn and crimson clover.
Peanuts, cotton and crimson clover, corn and crimson clover, soybeans and crimson clover.
Peanuts, potatoes, corn and crimson clover, soybeans and crimson clover, corn and rye.
Early potatoes and corn, oats, clover.
Potatoes and corn, early cabbage and soybeans or spinach.
Potatoes and soybeans or cowpeas, sweet potatoes and crimson clover, corn and rye.

Dodson (1908) recommends the following rotations for cotton farmers in Louisiana:

Cotton, cotton, corn and cowpeas, oats and cowpeas.
Cotton, cotton, corn and cowpeas, oats and lespedeza.
Cotton, corn and cowpeas, oats and cowpeas.

He suggests the substitution of sorghum or sweet potatoes for part of the corn in these rotations and emphasizes the importance of having a legume on the land at least every third year.

The rotations of the corn belt are usually corn, small grain and clover or some variation of it. Sometimes the rotation is lengthened by addition of grass to the clover, the mixture being left for another year. In other cases alfalfa may be substituted for clovers and grasses and allowed to remain two or more years. In recent years soybeans have become important in parts of the corn belt; and when grown in the rotation, they are usually placed between the corn and the small-grain crops.

Difficulties and Limitations of Crop Rotations.—Rotations are not always advisable. There may be special conditions, such as extremely

high prices, which may make it advisable to grow only one crop for a long period. In case of silage corn, which is very heavy and bulky, it may be desirable to grow it on a field near the barn each year, manure and commercial fertilizers being used to keep the soil in proper condition. Weather conditions or other accidents may interfere with the rotation. Soils may be suited for only one or two crops. In trucking sections the prospective demand for a certain crop may make it advisable to substitute the crop for some other crop and thus break the rotation. However, in most cases it will be found advisable to establish a rotation made up of crops well adapted to the section and adhere to it through periods of high and low prices.

Effects of Continuous Cropping.—Under ordinary conditions continuous cropping lowers the productivity of the soil. This result may be due to one or more of several factors. (1) The constant removal of crops without the addition of organic material exhausts the soil humus and as a result the mechanical condition of the soil becomes poor. (2) If the mineral elements are not returned to the soil, one or more of them may be reduced to such an extent that profitable crops can no longer be produced. (3) If no legumes are grown, nitrogen may become the limiting factor in crop production. (4) The bases may be used up or leached out of the soil; thus it may become acid and unfit for the production of many crops. (5) Erosion may carry away considerable plant nutrients from the soil. However, productivity may be maintained if the soils are properly handled. Examples may be seen in all of the older agricultural sections of our country. Although the Shenandoah Valley of Virginia is one of the oldest agricultural sections of the country, the soils are apparently not decreasing in productivity. In the Piedmont section of Virginia, lands which have been cropped constantly ever since the earliest settlement of the country are still productive and many of them under proper handling seem to be improving in productivity.

The proper rotation of crops in itself cannot maintain soil productivity but it is one of the chief essentials in keeping up crop yields.

CHAPTER XXVI

CROP INSECTS AND DISEASES

CROP INSECTS

There are numerous insect enemies which attack field crops, and these are being added to from time to time by new insects introduced from other countries. Some of our worst insects pests have been imported. For example, the cotton boll weevil, pink bollworm and bean bettle have come to us from Mexico. The annual loss from destruction by insects is enormous.

Extent of Damage by Insects.—It is difficult to estimate properly the annual losses to field crops due to ravages of insects. The usual method of calculating such losses is to estimate the loss in units of measure for the different crops, multiply this by the current price per unit and express the loss in dollars and cents. This method is obviously faulty as it is a well-known fact that large crops, for the country as a whole, ordinarily sell for a lower price per unit than smaller crops. As an illustration, if the wheat crop of the world were reduced 25 per cent by insects, wheat would sell for a higher price per bushel than would be the case if this reduction did not occur. However, the loss of 25 per cent of a crop in individual cases would not have much effect on crop prices but would be very serious to the farmer.

Cereal crops are injured by many insects. The Hessian fly, which is chiefly injurious to wheat but which also attacks barley and rye to a lesser extent, may in extreme cases reduce yields so much that the crop will not pay the expense of harvesting. The wheat jointworm, which attacks only wheat, ranks next in importance to the Hessian fly and often reduces the wheat crop by millions of bushels. Chinch bugs and corn ear worms also cause great reduction in yields in sections where they are prevalent.

A number of insects which attack the hay and forage crops cause in aggregate large losses. The insects causing most serious losses in these crops are the army worms and grasshoppers. The ravages of these insects are most serious to individuals as in some cases the pests destroy the entire crop on a farm or in a community. There is also serious injury from insects which live underground, in their larval stage, such as cut-worms, webworms, white grubs and wireworms.

The boll weevil and bollworm are the most serious enemies of cotton. The loss due to these insects has been so severe in sections of the South

that cotton has become unprofitable and has been abandoned. The tobacco crop is also seriously reduced in value by such insects as flea beetles, hornworms and budworms. These insects lower the value of the crop by eating holes in the leaves and thus reducing its quality.

There are also many insects, such as the rice or black weevil, the Angoumois grain moth and the cigarette beetle, which attack stored crops and seriously reduce their quality.

How Insects Damage Crops.—Insects attack crops both in the field and in storage. The nature of the damage varies with the insect. In the field the injuries bring about a decrease in yield and often a reduction in the marketability of the product. In storage the damage results in a decrease in quality of the product, and this decrease often greatly reduces the selling value on the market.

The Hessian fly and the jointworm reduce the yield of wheat by both using and interfering with the passage of the juices of the young plants and by causing lodging of the older plants. The army worm injures or destroys plants by defoliation of the vegetative parts. The root system of plants is injured by some insects such as wireworms, white grubs and the corn root aphis. The cotton boll weevil and bollworm reduce the yield of the cotton crop by injury to the bolls. The corn borer is destructive to the plants because of the damage of the larvae to the stalk. The corn crop is injured by the corn ear worms in that they lessen the market value of the ears and make the grain more susceptible to disease.

Knowledge of Life Histories of Insect Pests Important.—It is very important to have a thorough knowledge of the life history of the various insects if they are to be effectively controlled and the losses resulting from their attacks reduced to a minimum. The life cycle of many of the insects varies and for this reason a study must be made of each insect. Accurate information comes only through careful, painstaking investigation, and it has been shown that the greatest injury is usually caused by the insects in their larval stages.

The Angoumois grain moth or fly weevil may infest grain either in the field or in the bin and the evidence of the infestation will appear later during storage. It has been shown that field infestation of corn is greatly reduced in the case of corn with long tight shucks. It has been definitely proved that late seedings of wheat usually escape the fall attacks of the Hessian fly. In the case of the boll weevil, early planting, selection of good varieties, good cultivation, early picking and destruction of the cotton plants after harvest will aid in reducing the ravages of this insect. In some cases attacks are worse on crops grown on the same land continuously, as in case of the Western corn root worm and corn root aphis.

Prevention of Insect Attacks.—In the reduction of losses from attacks of insects, the most effective and profitable methods are those which are preventive rather than curative. In planning their farming opera-

tions too few farmers think of the probability of insect attacks. The nature and activities of the various insects must be known in order to use preventive measures properly. Among the preventive measures rotation of crops and clean farming are of much value.

Rotation of Crops.—Rotation of crops is not only important in preventing attacks of insects but in maintaining and increasing crop yields. Some attacks of insects seem to be much worse when the land is cropped continuously to the same crop. This fact may be well illustrated in the instances of the Hessian fly and the Western corn root worm. In the rotation, care should be used to prevent crops coming together which are attacked by the same insects. Thus, by proper rotation the pests may be deprived of a source of food.

Clean Farming.—Clean farming ranks in importance with rotation of crops in preventing losses from insect attacks. Many insects hibernate over winter in the remains of the crop left in the field, in rubbish and in weeds. These materials should be plowed under, burned or destroyed in some way when losses from insects which may live in them are likely to ensue. The wheat jointworm frequently hibernates in the stubble of the crop and the same is true of the chinch bug in corn. Burning the stubble will aid in destroying the insects.

Other Measures.—Good preparation of the seedbed, timely plowing, judicious use of fertilizers, seeding at the right time, proper cultivation of the crops, opportune harvesting and proper storage are factors entering into the consideration of saving crops from insect losses.

CROP DISEASES

All crops suffer from diseases. The loss is often considerable but it can be greatly reduced by the use of proper methods of control which are based on a knowledge of the nature, cause and mode of dissemination of the disease.

Economic Importance of Diseases of Crop Plants.—Fortunately not all diseases which attack plants cause severe losses. In many cases, however, the losses reach a large amount. A small amount of damage from each disease attacking a crop may mean a great destruction in the aggregate. This statement will be appreciated when it is realized that there are more than 20 distinct fungous diseases of wheat in the United States. Humphrey (1917) states that the average annual damage due to cereal smuts is, in case of wheat, 20,000,000 bushels; oats, 50,000,000 bushels; barley, 6,000,000 bushels; and corn, 15,000,000 bushels. Diseases usually do a small percentage of damage to an individual field, but at times the entire crop is destroyed. In the latter instances the effect is very noticeable, while in the former instances the losses often pass unobserved or receive little attention.

Many of the heavy losses are caused by preventable diseases, and it is important that more attention be given to combating the ravages of crop diseases. In many cases the methods are simple, easily followed and very effective when used.

Knowledge of the Life History of a Disease is Important.—It is necessary to know the life history of a disease if it is to be successfully controlled. The importance of this information may be well illustrated by reference to certain diseases. The formaldehyde treatment is effective in controlling bunt of wheat but ineffective in preventing the loose smut. A knowledge of the life histories of these two fungi makes clear the difference resulting when the formaldehyde treatment is used. Where a disease is seed borne, seed selection is often advisable; in other cases seed selection is of little importance in controlling the trouble. The late blight of potatoes is disseminated almost entirely by planting diseased tubers, while the early blight fungus is not spread in this manner. Seed selection is an important method of controlling cotton anthracnose, while it is of no importance in controlling root knot of cotton. In case of diseases carried in the soil, rotation of crops is advisable, those crops being used that are immune or resistant to the disease in question. Crop rotation is an important factor in controlling cotton root knot and common potato scab.

Control of Diseases.—The toll reaped by plant diseases reaches such an enormous figure that the importance of controlling the diseases is at once evident. It is not practicable to attempt to control some of the diseases: for others there is no known efficient remedy; but there are many diseases the ravages of which can be profitably reduced. It is more profitable to use preventive than curative measures.

Curative Measures.—As a rule curative measures are too expensive to be practicable. The value of an individual plant is usually too small to allow much expenditure of time and money in attempting to effect a cure when it becomes diseased. This is especially true with most of the annual and biennial plants. On the other hand, curative methods may be recommended in the case of certain valuable perennial plants. The prevention of disease attacks is more economical and more effective than any curative means.

Prevention of Diseases.—Many of the diseases which cause great destruction can be largely controlled by certain preventive measures. These measures are frequently practiced at a very small cost, especially when compared to the damage likely to result to the crop if the diseases are allowed to develop. Most of the preventive remedies now used are the result of patient, careful, laborious and scholarly investigations.

Some of the methods used in preventing diseases of field crops are as follows: (1) the destruction of the organism on the seed, as in the case of the smuts of wheat; (2) protection by the application of sprays on the

growing plants, as when potatoes are sprayed with Bordeaux mixture to prevent infection of blight; (3) destruction of complementary hosts, as exemplified by the removal of the common barberry in reducing black stem rust infection; (4) avoidance of the use of materials carrying the disease—the common scab of potatoes may be disseminated by using infected manure; (5) selection of disease-resistant varieties or strains—the wilt of cotton and the root knot of cowpeas are reduced to a large degree by the use of resistant varieties; (6) avoidance of methods that will distribute the disease—blackfire of tobacco is spread more readily if the plants are cultivated when the leaves are wet than when dry; (7) the use of a rotation of crops—this measure is important in controlling early blight of potatoes; (8) selection of disease-free seeds, as in the case of late blight of potatoes, cotton anthracnose and corn root rot.

CHAPTER XXVII

GRAIN GRADING[1]

The subject of grain grading and standardization is an important phase of agronomic work which has recently been given much prominence by the teachers of farm crops in the various agricultural colleges. The outline given by Wentz (1920) has been followed closely in the preparation of this chapter.

Historical.—According to Miles (1919) grain inspection as it is now known originated in Chicago in 1857 under the auspices of the old Board of Trade. The only grades recommended were for Red Winter wheat, the classification being Red Winter or No. 2 Red Winter according to apparent quality. There were no grades proposed for spring wheat, white winter wheat, corn or oats. Because of complaints against certain unethical practices in grain dealing, the Chicago Board of Trade appointed a grain inspection committee. The committee on June 15, 1858, appointed a chief grain inspector and named grades to apply to grain. The grades established were: Chicago Club wheat, No. 1 Spring wheat, No. 2 Spring wheat, Rejected Spring wheat, No. 1 White wheat, No. 1 Red Winter, No. 2 Red Winter, Rejected Red Winter. Grades No. 1 and No. 2 and rejected were assigned to corn, oats, barley and rye. The grades were not defined or interpreted, the applications being left to the Chief Grain Inspector assisted by the Grain Inspection Committee.

In 1866 the Board of Trade of the City of Chicago Inspection Committee, which was formed in 1859, established a revised set of grades and defined the various grades. The system of grades established at this time was maintained, with frequent revisions and amplifications, until the United States Grain Standards Act was enacted in 1916.

Following the action taken in Chicago all other markets dealing in grain in a large way had by 1870 established grain inspection rules and methods for their enforcement. The first state to undertake the inspection of its grain was Illinois and its first inspector was appointed in 1871. Many states now have grain inspection laws but frequently they are not enforced.

Faults of the Early Grades.—The grades were frequently inadequately defined and interpreted and there was a lack of uniformity. Such a condition was to be expected since there was no precedent by which to establish rules and regulations and no close connection between the

[1] The grades for rye are given in U. S. Dept. Agr. Circ. 246 (1922).

grain inspectors and the members of the exchanges. There was a lack of cooperation on the part of the country shippers, and only a meager knowledge of the factors essential to proper grading was possessed.

Conditions Leading to Government Supervision.—As the grain trade increased in magnitude, more efficient inspection service was demanded. About 1890 the Illinois State Inspection Department emphasized the desirability of uniform grades. In 1902 the Chief Inspectors' National Association adopted rules and recommended them for general use but they did not receive universal endorsement. Following this action, in 1906, a Uniform Grade Congress was called in Chicago under the auspices of the Grain Dealers' National Association and it was decided to cooperate with the United States Department of Agriculture in fostering grain standardization.

Not only was there yet no authority for enforcement of the rules promulgated, but there was no body to interpret them or see that they were properly applied. The same lot of grain might receive one grade on one market and another grade on another market. At times the grade of one market was not recognized by another market. There was but little stability to the system, and such a condition brought about a demand for uniform rules applicable to all markets.

As a result of the desire for universally uniform rules, it was suggested that Federal control be exercised but this suggestion was objected to by state inspection departments. There then followed a suggestion for Federal supervision. As a result of this, there was enacted in 1916, the United States Grain Standards Act.

United States Grain Standards Act.—The Federal government, realizing the need of uniform standards and grades for grain, passed on August 11, 1916, the United States Grain Standards Act. As stated by Brown and Smith (1919):

> The purpose of the Act is to provide for the establishment of a single set of standards of quality and condition for the various grains, and to provide for their uniform application to the shipments by grade in interstate and foreign commerce. The Act specifically prohibits the use of any other grades whatsoever for any grain which comes under its requirements.

The passage of this Act has been very useful to the farmer, manufacturer and consumer.

Value in Foreign and Interstate Trade.—The provisions of the Grain Standards Act guarantee to the buyer of grain in interstate or foreign commerce that, if the grain is bought according to the Federal grades, the product shall meet certain specified, uniform requirements of the grade named, without regard to the source of the product. Thus, wheat marked No. 1 Northern Spring denotes that the grain has certain definite qualities regardless of its place or conditions of production. To the

person well versed in grain dealing in this country, the name of a particular grade of grain carries with it certain characteristics peculiar to the grade in question. Thus, uniformity is established.

Effect upon Intrastate and Local Trade.—The Federal Act does not apply specifically to trade other than interstate and foreign trade. However, grain of intrastate and local trade can be bought and sold by the Federal standards. The United States Department of Agriculture cooperates in acquainting farmers and millers with the standard grades through various educational means. Samples of grain may also be sent to the recognized or licensed inspectors who will report on the quality of the sample, assigning it the proper Federal grade. The handling of grain of intrastate and local trade entirely on the basis of the Federal grades will avoid much misunderstanding, bring more profit to the producer and miller and encourage the production of better quality grain.

Effect upon the Farmer.—When both the farmer and the buyer have become educated to the use and value of the Federal grades, their transactions will be based on the quality of the product in question. Too often the grain of a certain section is bought on the basis of the average product of the section. This means that the farmer who produces a poor product receives too much, while the farmer who produces a prime product receives too little in comparison. In short, a premium is placed upon inferior grain. There is not much incentive, under such conditions, for the more progressive growers to produce high market quality grain. When the farmer who produces No. 1 wheat or corn receives more than the producer of No. 2 grades, then more grain of high quality will be produced upon the American farms. The producer of premium grains should receive higher consideration because of the extra care, labor and money which he has expended.

Federal Classification and Grades.—The Federal standards provide for certain classes and grades of wheat, corn, oats and rye to be followed in grain grading and inspection work.

Wheat.—Under the definition of the Federal Grain Standards Act wheat is any grain which, when free from dockage, contains 90 per cent or more of wheat grains. The term "wheat" in these standards does not include emmer, spelt and einkorn. There are five classes of wheat, each of which is divided into three subclasses, with the exception of Class IV which contains two subclasses. Each subclass contains six grades. They are Nos. 1, 2, 3, 4, 5 and sample. The classes and subclasses are as follows.

Class Number and Name of Wheat	Name of Subclass
Class I, Hard Red Spring	(a) Dark Northern Spring (b) Northern Spring (c) Red Spring
Class II, Durum	(a) Amber Durum (b) Durum (c) Red Durum
Class III, Hard Red Winter	(a) Dark Hard Winter (b) Hard Winter (c) Yellow Hard Winter
Class IV, Soft Red Winter	(a) Red Winter (b) Western Red
Class V, White	(a) Hard White (b) Soft White (c) Western White

Hard Red Spring wheat (Class I) includes all varieties of hard red spring wheat, and may include not more than 10 per cent of other wheat or wheats. The *Dark Northern Spring* subclass includes wheat of the class Hard Red Spring consisting of 75 per cent or more of dark, hard and vitreous kernels. It does not include more than 10 per cent of wheat of the variety Humpback. The *Northern Spring* subclass includes wheat of the class Hard Red Spring consisting of less than 75 per cent and more than 25 per cent of dark, hard and vitreous kernels. It does not include more than 10 per cent of wheat of the Humpback variety. The *Red Spring* subclass includes wheat of the class Hard Red Spring consisting of not more than 25 per cent of dark, hard and vitreous kernels. It also includes wheat of the class Hard Red Spring consisting of more than 10 per cent of the Humpback variety.

Durum wheat (Class II) includes all varieties of durum wheat, and may include not more than 10 per cent of other wheat or wheats. The *Amber Durum* subclass includes wheat of the class Durum consisting of 75 per cent or more of hard and vitreous kernels of amber color. It does not include more than 10 per cent of wheat of the Red Durum variety. The *Durum* subclass includes wheat of the class Durum consisting of less than 75 per cent of hard and vitreous kernels of amber color. It does not include more than 10 per cent of wheat of the Red Durum variety. The *Red Durum* subclass includes wheat of the class Durum consisting of more than 10 per cent of the Red Durum variety.

Hard Red Winter wheat (Class III) includes all varieties of hard red winter wheat, and may include not more than 10 per cent of other wheat or wheats. The *Dark Hard Winter* subclass includes wheat of the class

Hard Red Winter consisting of 80 per cent or more of dark, hard and vitreous kernels. The *Hard Winter* subclass includes wheat of the class Hard Red Winter consisting of less than 80 per cent and more than 25 per cent of dark, hard and vitreous kernels. The *Yellow Hard Winter* subclass includes wheat of the class Hard Red Winter consisting of not more than 25 per cent of dark, hard and vitreous kernels.

Soft Red Winter wheat (Class IV) includes all varieties of soft red winter wheat. It also includes red club and red hybrid wheats of the Pacific Northwest, and may include not more than 10 per cent of other wheat or wheats. The *Red Winter* subclass includes wheat of the class Soft Red Winter consisting of both light- and dark-colored kernels. It does not include more than 10 per cent, either singly or in any combination of Red Russian, red clubs, red hybrids, and other soft red winter wheats possessing the characteristics of those varieties as grown west of the Great Plains area of the United States. The *Western Red* subclass includes wheat of the class Soft Red Winter consisting of more than 10 per cent, either singly or in any combination, of Red Russian, red clubs, red hybrids and other soft red winter wheats possessing the characteristics of those varieties as grown west of the Great Plains area of the United States.

White wheat (Class V) includes all varieties of white wheat, whether winter or spring grown, and may include not more than 10 per cent of other wheat or wheats. The *Hard White* subclass includes wheat of the class White consisting of 75 per cent or more of hard (not soft and chalky) kernels. It does not include more than 10 per cent of wheat of the varieties Sonora and White Club, either singly or in any combination. The *Soft White* subclass includes wheat of the class White consisting of less than 75 per cent of hard (not soft and chalky) kernels. It does not include more than 10 per cent of wheat of the varieties Sonora and White Club, either singly or in any combination. The *Western White* subclass includes wheat of the class White consisting of more than 10 per cent of the varieties White Club and Sonora, either singly or in any combination.

Mixed wheat is any mixture of wheat not provided for in the Classes from I to V, inclusive.

An abridged tabulation of the grades for wheat with brief explanations is given in Table LXXXVII.

TABLE LXXXVII.—ABRIDGED TABULATIONS OF THE GRADES FOR WHEAT WITH BRIEF EXPLANATIONS

(The Numbered Footnotes Below Must be Read in Connection with the Tabulation)

	Minimum limits of test weight per bu.			Maximum limits of						
				Moisture		Damaged kernels		Foreign material other than dockage		Wheats of other classes
Grade No.	Class Hard Red Spring, lb.	Classes Durum, Hard Red Winter, White and subclass Red Winter, lb.	Subclass Western Red, lb.	Classes Hard Red Spring and Durum, per cent	Classes Hard Red Winter, Soft Red Winter and White, per cent	Total, per cent	Heat damage, per cent	Total, per cent	Matter other than cereal grains, per cent	Total, per cent
1	58	60	58	14.0	13.5	2	0.1	1	0.5	5
2	57	58	56	14.5	14.0	4	0.2	2	1.0	10
3	55	56	54	15.0	14.5	7	0.5	3	2.0	10
4	53	54	52	16.0	15.5	10	1.0	5	3.0	10
5	50	51	49	16.0	15.5	15	3.0	7	5.0	10
Sample[1]										

[1] *Sample Grade.*—This grade shall be wheat of the appropriate subclass which does not come within the requirements of any of the grades from No. 1 to No. 5, inclusive, and which has no commercially objectionable foreign odor, except of smut, garlic or wild onions. Moreover, this grade must not be very sour, hot or infested with live weevils or other insects injurious to stored grain, and it must not be in process of heating. Also, it must not be of distinctly low quality, or contain small, inseparable stones or cinders.

1. The wheat in grade Nos. 1 to 4, inclusive, shall be cool and sweet.
2. The wheat in grade No. 5 shall be cool, but may be musty or slightly sour.
3. The wheat in grade No. 1 Dark Northern Spring and grade No. 1 Northern Spring may contain not more than 5 per cent of the Hard Red Spring wheat variety Humpback.
4. The wheat in grade No. 1 Amber Durum and grade No. 1 Durum may contain not more than 5 per cent of the Durum wheat variety Red Durum.
5. For each of the subclasses of the class Durum, grade No. 1 and grade No. 2 may contain not more than 2 and 5 per cent, respectively, of Soft Red Winter and White Wheat, either singly or in any combination.
6. For each of the subclasses of the classes Hard Red Spring and Hard Red Winter, grade No. 1 and grade No. 2 may contain not more than 2 and 5 per cent, respectively, of White and Durum wheat, either singly or in any combination.
7. ach of the subclasses of the classes Soft Red Winter and White, grade No. 1 and grade No. 2 may contain not more than 2 per cent, respectively, of Durum wheat.

Corn.—Under the Federal Grain Standards Act corn is defined as shelled corn of the flint or dent varieties. There are three classes of corn and seven grades for each class. The classes are White, Yellow and Mixed. The grades of each class are as follows: Nos. 1, 2, 3, 4, 5, 6 and sample.

White corn is corn of which at least 98 per cent by weight of the kernels are white. A slight tinge of light straw color or of pink in kernels of corn otherwise white does not affect their classification as white corn.

Yellow corn is corn of which at least 95 per cent by weight of the kernels are yellow. A slight tinge of red on kernels of corn otherwise yellow does not affect their classification as yellow corn.

Mixed corn is corn of various colors not coming within the limits for color as provided in the definition of white corn and yellow corn. White capped yellow kernels are classified as mixed corn.

An abridged tabulation of the grades for corn with brief explanations is given in Table LXXXVIII.

TABLE LXXXVIII.—ABRIDGED TABULATION OF THE GRADES FOR CORN WITH BRIEF EXPLANATIONS

Grade No.	Minimum test weight per bu., lb.	Maximum limits of			
		Moisture, per cent	Foreign material and cracked corn, per cent	Damaged corn	
				Total, per cent	Heat damage, per cent
1	55	14.0	2	2	0.0
2	53	15.5	3	4	0.1
3	51	17.5	4	6	0.3
4	49	19.5	5	8	0.5
5	47	21.5	6	10	1.0
6	44	23.0	7	15	3.0
Sample[1]...					

[1] *Sample Grade.*—The sample grade shall be White corn, or Yellow corn, or Mixed corn, respectively. The grade must not come within the requirements of any of the grades from No. 1 to No. 6, inclusive; it must have no commercially objectionable foreign odor; it must not be heating, hot, infested with live weevils or other insects injurious to stored grain; and it must not be otherwise of distinctly low quality.

1. The corn in grades Nos. 1 to 5, inclusive, shall be cool and sweet.
2. The corn in grade No. 6 shall be cool but may be musty or sour.

Oats.—Under the definition of the Federal Grain Standards Act oats are any grain which consists of cultivated oats and not more than 25 per cent of foreign material, other grains and wild oats, either singly or in any combination. The classification of oats is based on color and the classes are designated as White, Red, Gray, Black or Mixed, according to the color of the oats. White oats include yellow oats. Oats are classed as White, Red, Gray or Black, respectively, when they consist of oats of such color, and not more than 10 per cent of other colors of cultivated and wild oats, either singly or in combinations. Mixed oats are all other oats. The oat grades are designated as Nos. 1, 2, 3, 4 and sample, White, Red, Gray, Black or Mixed, as the case may be, according to the respective requirements thereof, except that in the case of Mixed oats the requirements as to the maximum percentages of other colors are disregarded.

Bleached oats are oats which in whole or in part have been treated by the use of sulphurous acid or other bleaching chemicals. Bleached oats are graded and designated according to the grade requirements of the

standards applicable to such oats if they were not bleached; and there is added to, and made a part of, such grades designation the word "bleached."

Clipped oats are oats which have the general appearance of having had the ends removed by an oat clipper. They are graded and designated according to the grade requirements of the standards applicable to such oats if they were not clipped; and there is added to, and made a part of, such grades designation the word "clipped."

An abridged tabulation of the grades for the various classes of oats with brief explanations is given in Table LXXXIX.

TABLE LXXXIX.—ABRIDGED TABULATION OF GRADE REQUIREMENTS FOR WHITE, RED, GRAY, BLACK, MIXED, BLEACHED AND CLIPPED OATS

Grade	Condition and general appearance	Minimum test weight per bu., lb.	Sound cultivated oats not less than, per cent	Heat-damaged oats or other grain, per cent	Foreign material, per cent	Wild oats, per cent	Other colors, cultivated and wild oats, per cent
				Not to exceed			
1	Shall be cool and sweet and of good color	32	98	0.1	2	2	2
2	Shall be cool and sweet and may be slightly stained	29	95	0.3	2	3	5
3	Shall be cool and sweet and may be stained or slightly weathered	26	90	1.0	3	5	10
4 Sample[1]	Shall be cool and may be musty, weathered or badly stained	23	80	6.0	5	10	10

[1]*SampleGrade.*—Shall be White, Red, Gray, Black, Mixed, Bleached or Clipped oats, respectively. This sample must not come within the requirements of any of the grades from No. 1 to No. 4, inclusive; it must not have any commercially objectionable foreign odor; it must not be heating, hot, sour, infested with live weevils or other insects injurious to stored grain; and it must not be otherwise of distinctly low quality.

1. The percentage of moisture in grades Nos. 1, 2 and 3 shall not exceed 14½ and in grade No. 4 shall not exceed 16.
2. In the case of White oats, No. 1 shall be cool and sweet and of good white or creamy white color.
3. 4 per cent of other colors is allowed in No. 1 Red, Gray or Black oats. This column does not apply to Mixed oats.
4. 10 per cent of other colors is allowed in No. 2 Red, Gray or Black oats.

Note.—It will be noted that no limits are specifically stated for damage other than heat and for other grains. These are taken care of by the minimum requirement for "sound cultivated oats" in each grade. The following examples illustrate the application of the tabulation:

(*a*) Aside from other requirements, such as condition and general appearance and weight per bushel, a lot of oats, to grade No. 1, must contain 98 per cent "sound cultivated oats." The remaining 2 per cent may be damaged grains, foreign material, other grains or wild oats, either singly or in any combination. The only limitation on this remaining 2 per cent is that not more than one-tenth of 1 per cent may be heat damaged.

(*b*) Aside from other requirements, such as condition and general appearance and weight per bushel, a lot of oats, to grade No. 3, must contain 90 per cent "sound cultivated oats." The remaining 10 per cent may be damaged grains, foreign material, other grains or wild oats, either singly or in any combination of these factors, except that there must not be over 1 per cent heat damaged, 3 per cent foreign material or 5 per cent wild oats.

(*c*) Aside from other requirements, such as condition, general appearance and weight per bushel, a lot of oats, to grade No. 4, must contain 80 per cent "sound cultivated oats." The remaining 20 per cent may be damaged grains, foreign material, other grains or wild oats, either singly or in any combination of these factors, except that there must not be over 6 per cent heat-damaged grains, 5 per cent foreign material or 10 per cent wild oats. The amount of these factors present cannot be added so as to permit 21 per cent, since grade No. 4 must contain at least 80 per cent "sound cultivated oats."

Organization to Carry Out the Provisions of the Act.—Through a system of inspections the provisions of the Federal Grain Standards Act are supervised by the authority of the Secretary of Agriculture. The inspections are made and supervised by licensed inspectors, grain supervisors, and a board of review who act subject to the rules and regulations made by the Secretary of Agriculture according to the Act.

Basis of Establishing Grades.—In order that grain may be classified in a particular grade it must fulfill all the requirements of that grade. For instance, should Hard Red Spring wheat have a test weight of 57 pounds per bushel, which is the official weight for grade No. 2, instead of 58 pounds, the official weight for grade No. 1, it must be placed in grade No. 2 although it meets all other requirements for grade No. 1.

Sampling.—In order to determine the grade of grain, it is imperative that a representative sample be obtained. It is at least 2 quarts in size, of which at least 1⅛ pints is enclosed in a clean, air-tight container and the remainder in a clean cloth sack. In securing the sample, one should use the grain trier or probe. After a representative sample is secured, it is often necessary to reduce it in size so as to make a careful analysis. A good apparatus for accomplishing this purpose is the Boerner sampling device or the modified Boerner sampler.

Grading.—The procedures used in grading wheat, corn and oats follow.

Wheat.—In case of wheat the determinations for dockage, moisture, temperature, odor, onions, garlic and live weevils or other insects injurious to stored grain are upon the basis of the grain including dockage. All other determinations are upon the basis of the grain when free from dockage.

Moisture.—To ascertain the grades, a moisture test is conducted on the sample in the air-tight can according to the method described by Duvel (1914). For the other determinations the portion of the sample in the cloth bag is used. The determination of odor, onions, garlic and live weevils or other insects injurious to stored grain is first made. The sample is then divided down to about 1,000 grams, the Boerner apparatus being used The 1,000-gram sample is used to determine the dockage.

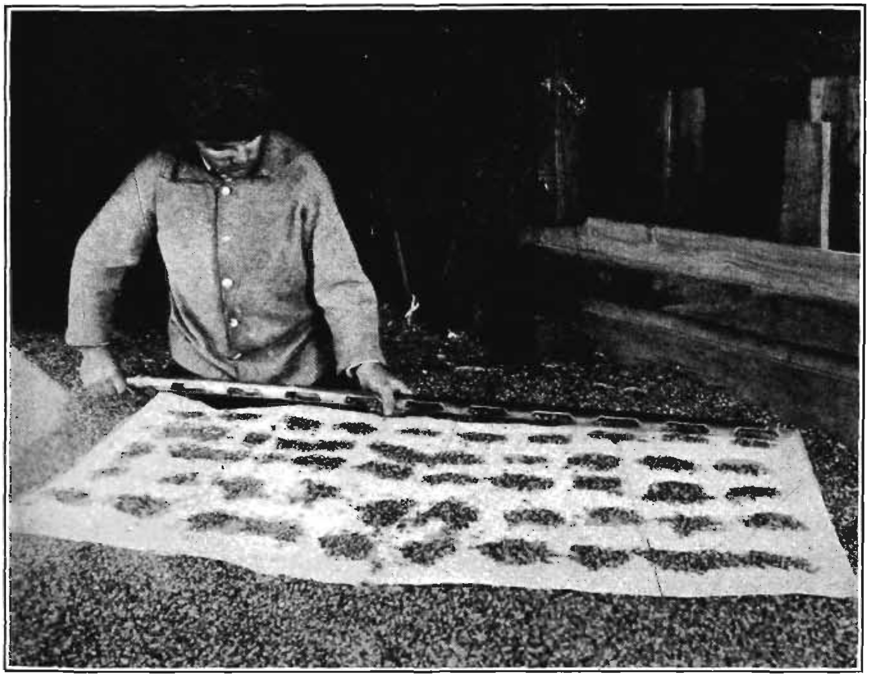

FIG. 35.—Securing the representative sample. The Federal sampler takes at least five probes from different parts of the car to procure a representative sample. The sampler is shown emptying the contents of the fifth probe on the sampling cloth. (*U. S. Dept. Agr., Bur. Agr. Econ.*)

Dockage includes such materials as sand, dirt, weed seeds, weed stems, chaff, straw, grains other than wheat and any other foreign material which can be readily removed by the methods indicated.

Weight per Bushel.—The test weight per bushel is determined, the dockage-free wheat remaining from the 1,000 grams being used.

Procedure.—The sample is now divided into three portions, A, B and C, containing 25 to 65 grams each. Portion A is used to determine the total damaged kernels, heat-damaged kernels, total foreign material and foreign material other than cereal grains. Portion B is used to determine the class and subclass into which the sample should be placed

by analyzing for color and texture. Portion C is used to determine wheats of other classes.

Corn.—In the case of corn each determination of color, damage and heat damage is made upon the basis of the grain after the removal of foreign material and cracked corn. All other determinations are made upon the basis of the grain including foreign material and cracked corn.

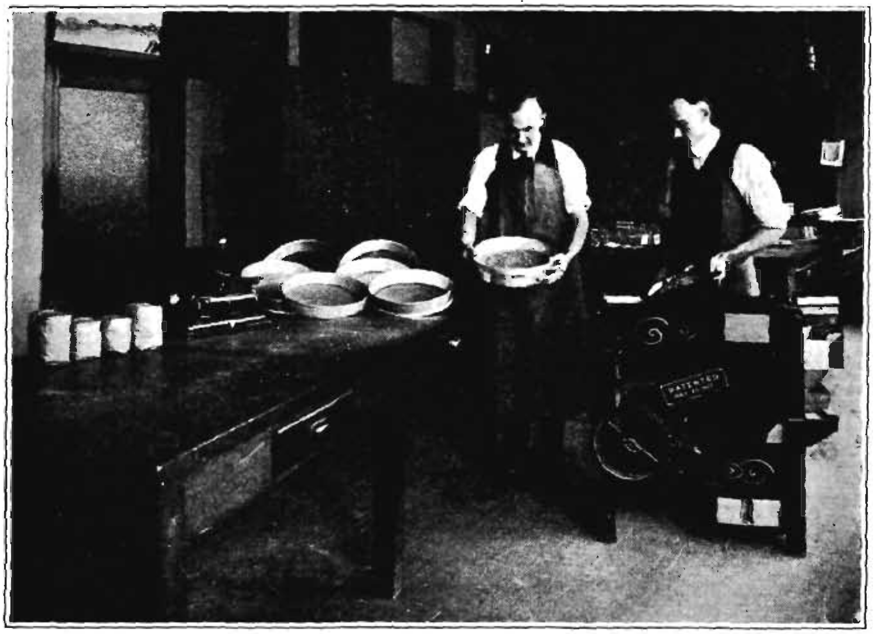

FIG. 36.—Determining the dockage in a wheat sample. The sample is first run through the wheat tester (wild oat kicker) to remove the coarse material, such as oats, chaff, straw, and the fine seed and dirt. The fine material is then rescreened with the standard hand sieve to recover to the sample as much of the small shriveled or broken kernels of wheat as is possible. The coarse material, together with the fine material after rescreening, is weighed to determine the amount of dockage, if any, that is to be assessed. (*U. S. Dept. Agr., Bur. Agr. Econ.*)

Procedure.—The moisture test is conducted as described for wheat. The next step in grading is to determine color, live weevil or other insects injurious to stored grain, and quality. The sample is then divided down to about 1,000 grams and the weight per bushel is determined, the 1,000-gram sample being used. The sample is divided down to 240 to 260 grams and the foreign material and cracked corn determined. Using the cleaned sample, determine total damaged and heat-damaged kernels. Divide down to about 100 grams and determine color using the 100-gram sample.

Oats.—In the grading of oats all determinations are made upon the basis of the lot of grain as a whole, including foreign material, other grains and wild oats.

Procedure.—The moisture test is conducted as given for wheat and corn. The condition and general appearance are determined and the sample is then divided down to a portion of 500 to 600 grams. The weight per bushel is determined, the 500-gram portion being used. The 500-gram portion is now divided into three parts, A, B and C, each containing 25 to 65 grams. Through the use of portion A, sound cultivated oats, heat-damaged (oats or other grains) and foreign material are then determined. When a sample contains an unusual amount of foreign material, the determinations for this factor should be made on not less than 250 grams of the original sample, the buckwheat sieve being used (Brown, 1920) for removing the seeds and dirt, and for recovering by rescreening any small pin oats that may pass through with the dirt. The sample should then be hand picked for any remaining foreign material. Portion B is used to determine the percentage of wild oats. Portion C is used to determine the percentage of other colors of cultivated and wild oats.

CHAPTER XXVIII

CEREALS

All the true cereals are grasses and their general characteristics are similar. There are many interesting comparisons between the characters of the cereals, even though there is much variation in details.

Germination and Seedling Development.—The first outward indication of germination in cereals is the emergence of the first roots, which are called temporary roots. These are developed from the radicle of the embryo. A short time after the appearance of the temporary roots the plumule, from which develops the upper portion of the plant, begins to emerge. The unfolding of the plumule is rather slow while the development of the root system is comparatively rapid. The temporary roots that develop may be as many as twelve in number. After the temporary roots have established themselves in the soil, the development of the plumule is comparatively more rapid. Thus far the developing seedling has received its nourishment largely from the endosperm. With the unfolding of the plumule, the further elaboration of food enables the plantlet to develop permanent roots, and then the temporary roots disappear.

Distribution of Roots.—The permanent roots are fibrous and extend outward and downward in all directions from the nodes of the shortened internodes of the stems at or below the ground line. The region of the shortened internodes is called the "crown." In the case of wheat, the main roots may penetrate to a depth of 4 feet or more, sometimes 5 or 6 feet, and even as deep as 7 feet. Moreover, the extent of branching and rebranching allows great development of the root system. Wheat, in common with all grasses, does not develop a tap root.

King (1892) in Wisconsin found in the case of corn that the permanent roots first spread laterally. After 9 days the roots extended both laterally and downward; at 18 days after planting some of the roots extended laterally 18 inches and downward about 12 inches. At 27 days after planting some of the roots had reached 24 inches laterally and 18 inches downward, with the tips 4 inches below the surface. At 6 inches from the hill no roots were nearer the surface than 2 inches. When the plants were 18 inches tall, 42 days after planting, the downward growth of the roots had reached 18 inches and the roots of two hills had met and passed each other in the center of the rows, which were 3½ feet apart. When the plants were 3 feet in height, the roots occupied the upper 2 feet of soil,

which was as deep as they could be measured in the experiment. It has been shown, however, that as the corn plant matures, the root system continues to increase and the soil is penetrated to a depth of 3 or 4 feet. Branch roots come nearer the surface of the soil as development continues, and near maturity many roots are close to the surface. Corn also develops aërial or brace roots which serve to brace the plant. After they enter the soil, they also aid in nourishing the plants.

Tillers.—Frequently we find more than one branch developing from the primary stem of cereal plants. These are known as tillers, and the number will depend on conditions. The conditions which favor growth, such as rich soil, abundant moisture and the proper temperature, usually also favor the development of tillers. It has been found that thick planting decreases the production of tillers, while thin planting favors tillering.

Culms.—The stems of grasses are known as "culms," and they are generally hollow except at the nodes. This is true of wheat, oats, rye and barley, with the exception of some of the wheats, such as the spelts, which are partly or entirely filled with pith. The culm of the corn plant, popularly called the "stalk," is filled with pith. The leaves are alternate, two-ranked and parallel-veined, as is common to all grasses.

Inflorescence.—The inflorescence of the cereals is usually terminal on the plant, as in the case of wheat, rye, barley, oats and the male inflorescence of corn. The type of inflorescence is somewhat variable. In oats it is a loose panicle; in wheat, barley and rye it is a spike-like panicle, which is more often called a "spike;" and in corn the pistillate inflorescence, which is borne on a lateral branch, is a thickened spike.

The inflorescence consists of a central stem, known as the "rachis," which is jointed. Branches, called "rachillas," arise from the joints and bear one or more flowers. The rachilla together with the flowers is called a "spikelet." Each spikelet is enclosed by two chaffy glumes and bears one or more flowers. As a rule, one or more seeds are produced.

Flowers.—The grass floret consists of one fertile or flowering glume, the lemma, often bearing an awn from the back or apex, and the palea; one ovary, at the base of which are two lodicules; and three stamens. The reproductive organs of the individual complete flower consists of an ovary bearing a style and two stigmas. The flower also has three stamens surrounding the pistil, each consisting of a slender stalk or filament and a versatile, terminal, 2-celled anther in which the pollen is produced.

With the exception of corn, the flowers of cereals correspond to the above description. In corn the stamens and pistils are borne in separate flowers on the same plant, as corn is a monoecious plant.

Structure of Cereal Seeds.—In the case of oats and barley the grain is, with the exception of certain hull-less types, enclosed in the flowering glume

and palea. These latter parts are called the hull. The grains of other cereals, with the exception of some wheats, such as spelt, emmer and einkorn, are removed from the hull in threshing.

The proportion by weight of hull to grain varies greatly, but in the case of oats the average is approximately 30 per cent hull and 70 per cent grain. The hull in the case of barley varies from 14 to 25 per cent, but the average is about 15 per cent.

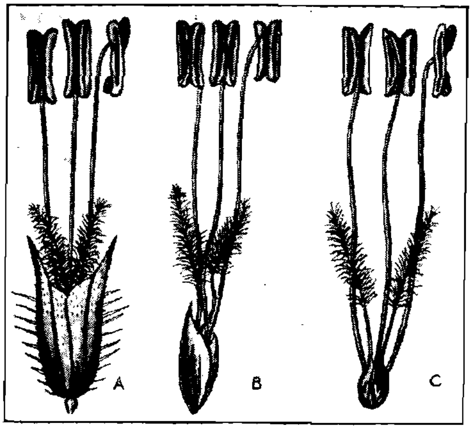

Fig. 37.—A floret of timothy: *A*, complete floret; the two hairy scales are the glumes; *B*, the glumes removed; the scale on the left is the lemma, that on the right the palea; *C*, the naked flower, consisting of three stamens and an ovary bearing two feathery stigmas; the two minute scales are the lodicules. (Much enlarged.) (*U. S. Dept. Agr. Farmers' Bull.* 1254).

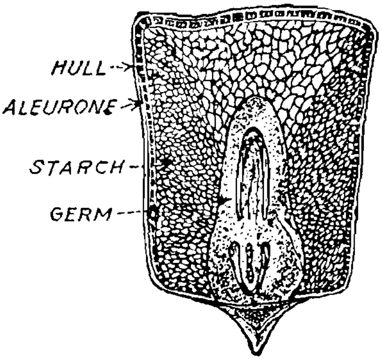

Fig. 38.—Diagram of corn kernel, showing the four principal parts: hull, aleurone layer, endosperm or starchy portion, and germ.

The four parts of a cereal grain are: (1) the protective covering, which consists of the seed coat proper or testa, and the pericarp or matured wall of the ovary; (2) aleurone layer; (3) endosperm; and (4) germ, as shown in Fig. 38. The proportions of these parts will vary in different cereal grains. According to Hopkins, Smith and East (1903) the protective covering, including the tip cap, constitutes about 7.5 per cent of the whole kernel of corn; the aleurone layer, 8 to 14 per cent; the endosperm, about 70 per cent; and the germ, about 11 per cent. Ingersoll and Bessey (1894) state that the protective covering of the wheat kernel constitutes about 5 per cent; the aleurone layer, 3 to 4 per cent; the endosperm, 82 to 86 per cent; and the germ, about 6 per cent.

Composition of Cereals.—The composition of the seeds of a cereal differs according to variety. The "hard wheats" frequently have 13 to 16 per cent protein, while the "soft wheats" often contain 8 to 11 per cent. In the case of barleys the percentage of protein frequently ranges from 8 per cent for the soft barleys to 15 per cent for the hard barleys. In corn grains

which have both hard and soft endosperm, the former is higher in protein. Hopkins and others (1903) report that the hard endosperm contains about 10 per cent protein and the soft 5 to 8 per cent. However, the differences found to exist between the hard and soft wheats and barleys are not found in hard and soft corns.

The composition of the cereal grains is shown in Table XC, taken from Chamberlain (1909).

TABLE XC.—TOTAL NUTRIENTS IN CEREALS, POUNDS PER HUNDRED ON WATER-FREE BASIS

Grain	Protein, lb.	Fat, lb.	Crude fiber, lb.	Carbo-hydrates, lb.
Oats	13.76	4.33	12.20	66.39
Wheat	14.20	2.36	2.78	78.72
Rye	13.44	1.83	2.30	80.24
Barley	13.39	1.87	5.64	76.05
Corn	9.91	4.40	2.21	81.96

The compositions of the corn grain and its parts, as reported by Voorhees (1894), and of the oat grain and its parts, as reported by Warburton (1910), are shown in Table XCI.

TABLE XCI.—COMPOSITION OF THE OAT GRAIN AND THE CORN KERNEL AND THEIR PARTS, POUNDS PER HUNDRED ON WATER-FREE BASIS

Cereal	Protein, lb.	Fat, lb.	Fiber, lb.	Carbo-hydrates, lb.	Ash, lb.
Oat:					
Grain	13.3	5.6	10.7	67.1	3.3
Kernel	16.0	7.7	1.0	73.1	2.2
Hull	3.6	1.1	32.0	56.1	7.2
Corn:					
Kernel	12.7	4.3	2.0	79.3	1.7
Skin	6.6	1.6	16.5	75.4	1.3
Germ	21.7	29.6	2.9	45.8	11.1
Starchy and hard part	12.2	1.5	0.7	85.6	0.7

Other analyses of these same cereals may vary widely from the above, but the data given will serve to indicate the approximate compositions and are of comparable value.

Ratio of Grain to Straw.—The proportion of grain to straw is not constant in cereals. The ratio will vary with such factors as the variety, thickness of planting and productivity of the soil. However, as a rule, barley produces 1 pound of grain to 1 of straw; wheat, 1 of grain to 1½ of straw; oats, 1 of grain to 2 of straw; rye, 1 of grain to 2 of straw; and corn, 1 of grain to 1 of stover.

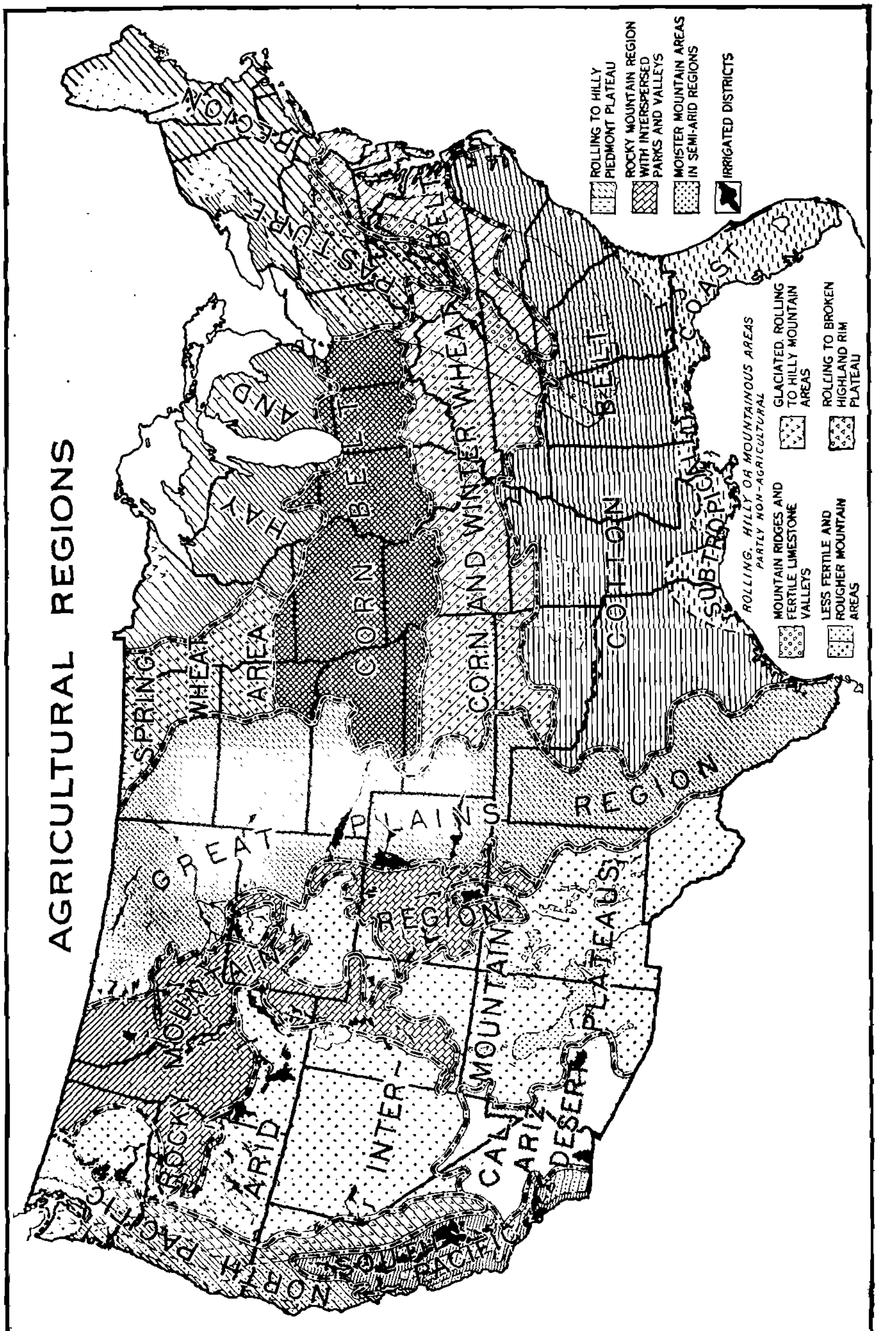

Fig. 39.—Outline map of the United States showing agricultural regions. (*U. S. Dept. Agr. Yearbook*, 1921).

CHAPTER XXIX

CORN (Zea mays)

Corn or maize is preeminently the grain crop of the United States. It is grown in nearly every part of the United States but reaches its greatest prominence in the corn belt. The value of the corn crop exceeds that of any other crop grown in this country. In nine of the last twelve years the value of corn has been more than the combined values of wheat and cotton. In eight of these years the corn crop was worth more than the combined values of all cattle and swine produced for slaughter. The average annual value of the corn crop from 1910 to 1914 was $1,577,000,000; from 1915 to 1919 the average annual value was $3,024,000,000; in 1920 the value was $2,150,000,000; and in 1921 the value was $1,303,000,000.

World Production.—Figure 40 shows the world production of corn for the 3-year period, 1919 to 1921.

Average Acre Yields.—The average yield of corn per acre for the 10-year period, 1910 to 1919, was for the United States, 26.2 bushels; Russia, 16.7 bushels; Italy, 24.7 bushels; Austria, 21 bushels; Hungary, 28 bushels; France, 17.8 bushels; and Argentina, 19.2 bushels

Production in the United States.—Figure 41 shows the acreage for the United States in 1919.

The average annual yield for the United States as a whole for the 5-year period, 1910 to 1914, was 2,732,457,000 bushels, with an average acre yield of 26 bushels; during the period 1915 to 1919 the average annual production was 2,788,184,000 bushels and the average acre yield was 26.4 bushels.

In 1920 the six states of Iowa, Illinois, Nebraska, Missouri, Indiana and Texas produced 1,580,648,000 bushels of corn, or 48.9 per cent of the entire crop.

Historical.—Corn was probably first cultivated in the high plateau region of central or southern Mexico. This region is the native habitat of teosinte and gama grass, which are closely related botanically to maize. The cultivation of maize probably started in this region about the beginning of the Christian Era. It spread rapidly both northward and southward, reaching the Rio Grande about 700 A.D. and Maine about 1000 A.D.

Maize was found under cultivation when Columbus discovered America, and soon after the discovery of the New World it was introduced into the Eastern Hemisphere. The culture of corn has spread rapidly

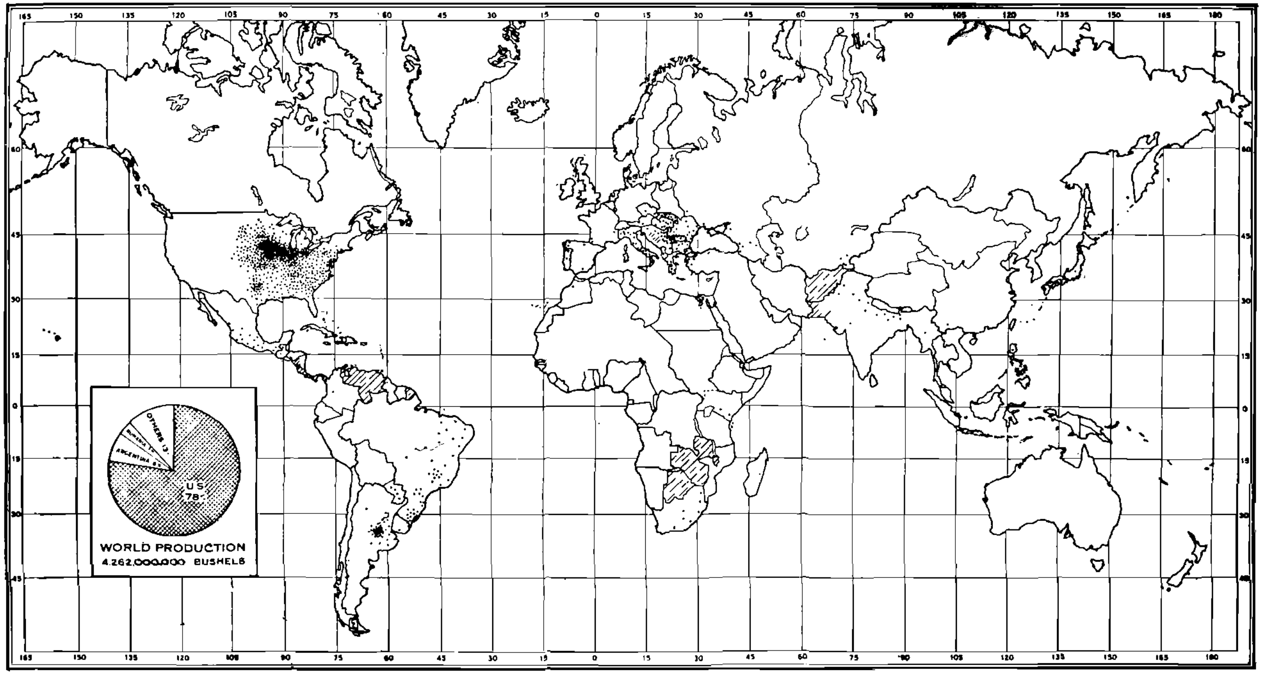

FIG. 40.—Corn production of the world, 3-year average, 1919–1921. Each dot represents 5,000,000 bushels. The United States produces three-fourths of the corn crop of the world. Corn is an important crop in Argentina, Brazil, Mexico, South Africa, India, and southern Europe. Its northern limits are found between 45 and 50 degrees latitude north, and its southern limits between 30 and 40 degrees latitude south. Quantity and distribution of summer rainfall are important factors in production within these limits. (*U. S. Dept. Agr. Yearbook*, 1921).

and it is a very important crop in the United States as well as in other countries. Leighty, Warburton, Stine and Baker (1922) state that the Virginia colonists planted 30 or 40 acres in 1609, and about 500 acres in 1614. In 1631, according to these authorities, there was a surplus of corn to export. The yield of corn in the United States increased from 377,531,875 bushels in 1839 to 3,208,584,000 bushels in 1920.

There are two semi-tropical plants related to corn which grow wild in the United States and Mexico. These are gama grass (*Tripsacum*

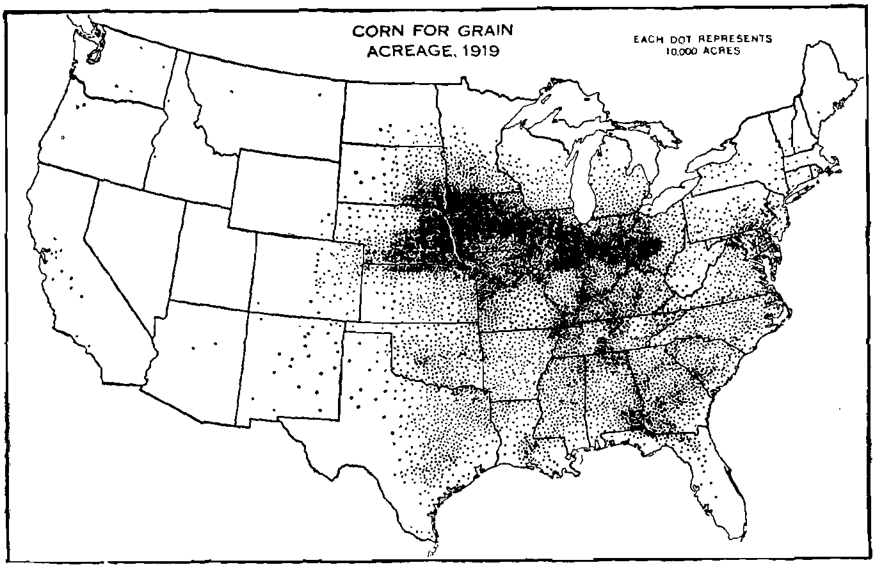

FIG. 41.—Over two-thirds of the corn acreage of the world is in the United States, nearly all east of the line of 8 inches mean summer rainfall and south of the line of 66 degrees mean summer temperature. Nearly 90 per cent of the acreage of corn for grain in the United States is in the corn belt, the corn and winter wheat region and the cotton belt. In these three regions corn constitutes about one-third of the acreage of all crops. In the corn belt it is dominant, contributing nearly two-fifths of the acreage and half of the value of all crops. (*U. S. Dept. Agr. Yearbook*, 1921).

dactyloides) and teosinte (*Euchlaena Mexicana*). It is probable that Indian corn and these two plants originated from a common remote ancestor which grew in Mexico. Gama grass is more slender than corn but has a tassel resembling the corn tassel, and the seeds are borne in the tassel, while teosinte is more like corn and bears a branched ear. Teosinte crosses readily with corn and to some extent with *Tripsacum*. It is probable that corn and *Tripsacum* do not cross.

Groups of Corn Varieties.—Corn may be classified into six principal types or groups. These types are pod corn, pop corn, flint corn, dent corn, soft corn and sweet corn. The classification is based largely on the character of the kernels.

Pod Corn (*Zea Mays tunicata*).—In this group each kernel is enclosed in a pod or husk, and the ear formed is also enclosed in husks. The plants are frequently very leafy and the tassels are often heavy and inclined to

FIG. 42.—*Durango teosinte.* (*Jour. Heredity, vol.* 3, *no.* 3, 1916).

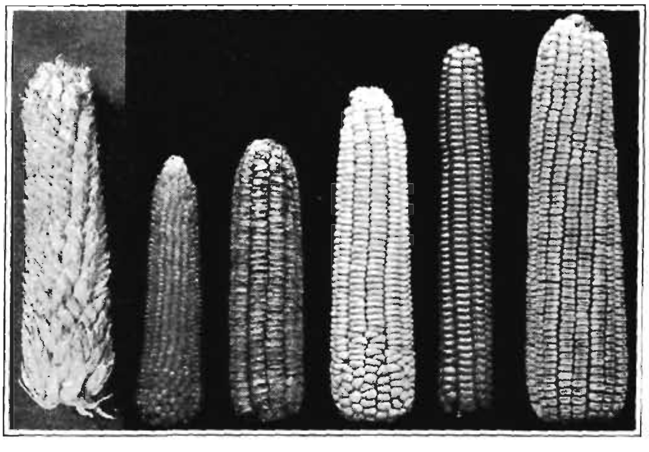

FIG. 43.—The six types of corn. Reading from left to right: pod, pop, sweet, soft, flint and dent. (With exception of the pod ear, *Courtesy of U. S. Dept. Agr., Cereal Investigations*).

bear kernels. Pod corn is sometimes known as cow corn, forage corn, husk corn, primitive corn and so forth.

Pop Corn (*Zea Mays everta*).—This group is characterized by a very hard, corneous endosperm and small kernels. The ability to pop is due to the explosion of moisture upon the application of heat. There are two main types of pop corn: rice, with pointed kernels, and pearl, with rounded kernels. The kernels vary greatly in color and size.

Flint Corn (*Zea Mays indurata*).—The endosperm is soft and starchy in the center and completely enclosed by a very hard outer layer. The kernels are usually rounded but are sometimes short and flat. The flint corns are early maturing and for this reason are suited for growing in cool climates and on high altitudes where dent corns will not mature. The kernels are of various colors.

Dent Corn (*Zea Mays indentata*).—In the case of dent corn there are both hard and soft starches. The hard starch extends on the sides and the soft starch is in the center and extends to the top of the kernels. In the drying and shrinking of the soft starch, various forms and degrees of indentation result. This group is the most widely cultivated group of corn and it is by far the most common one in the corn belt. The plants vary in height from 6 to 18 feet, the ear, in length from 6 to 12 or 14 inches, and the rows on the ears, from 8 to 24.

Soft Corn (*Zea Mays amylacea*).—The kernels of soft corn are composed entirely of soft starch. All colors exist, but white and blue are most common and the kernels are shaped like flint kernels. This group is also known as flour corn and as squaw corn.

Sweet Corn (*Zea Mays saccharata*).—The kernels of sweet corn are translucent, horny and more or less wrinkled in appearance. It has a sweeter taste than other corns as the endosperm contains sugar as well as starch.

There are many other types of corns but they are of comparatively little importance.

Varieties.—The choice of the variety or varieties of corn to grow will depend upon soil, climate and the use to which the crop is to be placed. The conditions vary to so great an extent over comparatively limited areas that recommendations as to varieties can be only general. Selection of the variety to use should be based largely upon the results secured by the nearest experiment station and upon the practice of the best farmers of the community.

There are a large number of named varieties of corn. Sturtevant (1899) has given a description of 507 varieties, of which 163 are synonyms. Of the 507 varieties, 323 are classified as dent corns, 69 as flint corns, 63 as sweet corns, 27 as soft corns and 25 as pop corns. Hartley (1922) has listed 487 varieties based on time of maturity. Of this number 62 require less than 100 days to mature; 282 require 100 to 125 days; and 143 require more than 125 days. There are probably a much larger number of named varieties of corn, many of which are of local impor-

tance; and no doubt the same variety has several names in many instances.

Varieties for the South.—In certain parts of the South, especially along the Gulf Coast, the prolific varieties of corn, by which are meant those commonly producing more than one ear to the stalk, are to be recommended. Of such varieties may be named Mosby, Cocke's Prolific, Blount's and Albermarle. To the large one-eared varieties grown in this section belong St. Charles White, Boone County White, Leaming and White Pearl. In the northern tier of the southern states these one-eared varieties are grown for grain, while the prolific varieties are grown for silage.

Varieties for the Corn Belt.—In the corn belt the single ear varieties are grown. Of the yellow varieties, Leaming, Reid's Yellow Dent and Riley's Favorite are popular. The popular white varieties are Silver Mine, Boone County White, Johnson County White and Commercial White. The early varieties used to a large extent are Pride of the North and White Cap.

Varieties for the Northern Central States.—In the northern Central states, in what is largely the small-grain region, the earlier varieties of corn are grown. Of the dent varieties grown in this section, Pride of the North, Minnesota No. 13, Silver King or Wisconsin No. 7, and White Cap are good. The varieties of flint corn grown are King Philip, Smut Nose and Eight-Row Yellow.

Varieties for the New England States.—In the New England states the flint varieties predominate. The popular varieties are King Philip, Sanford White, Smut Nose, Eight-Row and Twelve-Row Yellow flints.

Varieties for Silage.—For silage purposes any of the above varieties of corns may be used. As a rule later maturing varieties are used for this purpose more than for grain. However, for silage, varieties of corn should not be grown which will not become nearly mature by harvest time.

Yellow Corn Compared with White Corn.—It has been the opinion of many farmers for a long time that yellow corn is superior in feeding value to white corn. Various chemical analyses did not show any marked, consistent differences in the composition of these two kinds of corn. However, in recent years it has been shown that yellow corn contains the fat soluble vitamine, while white corn does not contain it. The feeding experiments reported by Russell and Morrison (1922) at the Wisconsin Experiment Station show yellow corn to be superior to white corn for feeding to hogs and other classes of live stock. The difference has been attributed to the difference in vitamine content.

Uses.—According to Leighty, Warburton, Stine and Baker (1922), of the corn crop harvested for grain, 40 per cent is fed to hogs on the farms; 20 per cent to horses and mules on the farms; 15 per cent to cattle

on the farms; 4 per cent to poultry on the farms; and 1 per cent to sheep on the farms. Of the remainder, 3.5 per cent is used as human food on the farms; 5.5 per cent is fed to live stock not on the farms; 6.5 per cent is ground in merchant flour mills, principally for food; 1.5 per cent is exported; and 3 per cent is used for other purposes. Thus, over 85 per cent of the grain corn is fed to animals.

In addition to the use of the grain, the corn plant is used in the form of silage, fodder and stover, as feed for animals. About 4,000,000 acres of corn are annually made into silage; more than 2,500,000 acres are cut for fodder; and over 2,000,000 acres are grazed or "hogged down."

Corn is prepared in many ways for human consumption. Among the corn products may be mentioned meal, grits, hominy, glucose or corn syrup and corn oil. Other products are germ meal, gluten feed and distillery residues.

CULTURE

Seed.—The importance of selection of seed corn for type and maturity has been shown by many experiments. Montgomery (1912) of Nebraska thinks that natural selection apparently will tend to isolate the higher yielding strains.

FIG. 44.—Self-pollination of corn decreases vigor. The plat on the left was grown from seeds inbred for two generations, that on the right from normally crossed seeds.

The careful selection of seed corn is of special consideration in those sections where the growing season is short and corn is not likely to become fully developed. The earlier strains of corn should be selected and stored in such a way as to become dry before freezing. The results reported by Kiesselbach and Ratcliff (1918) from Nebraska show that early-established corn which is properly stored germinates better than late-selected seed. Duvel (1904) has shown that seeds containing a low percentage of moisture deteriorate much less in storage than seeds containing large amounts of moisture.

Seed corn may be selected from the crib, at husking time or in the field from the standing stalks. Field selection is best, since at this time the early-maturing ears can be secured, the conditions of growth, such as

soil and stand, can be studied, the characteristics of the plant and the location of the ear can be observed and the ears can be carefully dried and stored.

Germination Test.—When there is reason to believe that the seed corn will not germinate satisfactorily when planted, a germination test should be made for each ear. In this test usually six or more kernels are removed from each ear at different places, and the viability determined.

FIG. 45.—Corn planting begins in the usual year before February 1 in extreme southern Texas, and at progressively later dates toward the north. It begins in the heart of the corn belt about May 1. Near the northern limits of corn production planting does not begin until about the middle of May. (*U. S. Dept. Agr. Yearbook*, 1921).

Time of Planting.—This will vary with the section of the country, as would be expected. The date of planting in the various sections is given in Chapter XIV. The date at which corn planting begins is shown graphically in Fig. 45. It will be noted from Fig. 45 that planting begins before February 1 in the extreme southern portions of Texas and at progressively later dates toward the north. The advance northward is at the rate of about 13 miles per day until May 1, when during the next 10 days planting begins throughout the northern states. In the corn belt, the planting season is at its height about May 15, and ends about June 1. In the South a second or late planting may be made. In any section the planting season usually extends over at least 2 weeks.

The results secured by Morrow and Gardner (1892) in Illinois indicate that corn should not be planted extremely early or extremely late if the best return is to be secured. Their results are presented in Table XCII.

TABLE XCII.—EFFECT OF TIME OF PLANTING ON YIELD AND ON PERCENTAGE OF MOISTURE IN CORN IN ILLINOIS

Date of planting	Data secured at husking, 1891				Bu. air-dry corn per acre (average 1888–1891)
	Lb. to make 1 bu. dry corn	Percentage of moisture in shelled corn	Bu. of shelled corn per acre	Bu. of air-dry corn per acre	
April 25	69.9	14.0	52.6	50.8	51
May 2	70.8	14.6	52.6	50.4	60
May 9	70.9	14.8	50.7	48.5	64
May 16	74.4	17.0	53.3	49.7	67
May 23	80.0	19.3	57.9	52.5	65
May 30	96.8	24.0	40.0	34.1	61
June 8	97.9	23.9	43.9	37.5	57
June 13	127.8	31.5	25.2	19.4	45

Depth of Planting.—Corn seeds should be planted deep enough to insure plenty of moisture for germination. The depth will, therefore, vary to some extent on different soils and under different climatic conditions. On heavy soils the seeds should be planted more shallow than on soils of open structure, such as those of a sandy nature. Corn is usually planted from 1 to 4 inches deep but the results secured by Hickman (1890) in Ohio, Latta and Anderson (1897) in Indiana and Morrow and Gardner (1894) in Illinois, do not show any increase in yield for planting deeper than 2 inches.

TABLE XCIII.—EFFECT OF DEPTH OF PLANTING ON YIELD OF CORN

Depth of planting. in.	Yield in bu. per acre		
	Average 6 yr., Ohio	Average 6 yr., Ind.	Average 5 yr., Ill.
1	56.6	38.7	77.5
2	51.2	39.2	71.5
3	46.8	37.8	65.1
4	....	....	68.7
5	....	....	61.3
6	....	....	60.0
7	....	....	40.5

Rate of Planting.—The rate of planting will vary with the soil, climate and variety of corn.

In the South, on the poorer soils, corn is often grown two stalks to the hill 4 or 5 feet apart each way. Farther north the stalks vary in number from two to four per hill in hills about 3½ feet apart each way.

Morrow (1891) in Illinois reports the 3-year average yield of corn from planting 11,880 kernels to be 81 bushels per acre; 5,940 kernels, 55 bushels; and 47,520 kernels, 59 bushels. The yield from 15,840 kernels per acre was 77 bushels and from 9,504 kernels, 72 bushels.

Montgomery (1909) in Nebraska reports that there is but little difference in yield when three, four or five plants are grown per hill, but the yield for one and two stalks is lower. The results are shown in Table XCIV.

TABLE XCIV.—AVERAGE RESULTS FROM PLANTING CORN AT VARIOUS RATES, 1903–1908. NEBRASKA EXPERIMENT STATION

Plants per hill	Yield per acre, bu.	Average weight of ear, oz.	No. of ears per 100 plants	No. of tillers per 100 plants	Two[1] ears plants per 100	Barren plants per 100	Yield of stover per acre, lb.
1	48.3	10.5	161	138	13.3	3.0	
2	67.7	10.6	15	60	4.9	4.8	5,984
3	75.5	9.4	95	25	2.4	6.9	5,972
4	76.7	8.2	82	10	0.8	8.3	6,692
5	76.3	7.4	77	3	1.1	10.8	6,969

[1] Four years only.

Mooers (1920) found under Tennessee conditions that one ana two kernels per hill gave about the same yield, which was greater than when three kernels were planted per hill.

On good soils, planting should be thicker than on poor soils. At the Illinois Experiment Station, Hume, Center and Hegnauer (1908) found thick planting on rich soils increased yield, while on poor soils the thinner planting gave better results. Their results have been averaged and given in Table XCV.

The results secured by Latta and Anderson (1897) in Indiana indicate that in dry years thin planting is preferable, while in seasonable years the difference is in favor of thick planting. The results are shown in Table XCVI.

TABLE XCV.—RATE OF PLANTING OF CORN ON RICH AND POOR SOILS IN ILLINOIS

Section	More than 50 bu. per acre		Less than 50 bu. per acre	
	2 kernels per hill	3 kernels per hill	2 kernels per hill	3 kernels per hill
Northern Illinois	57.9	68.5	41.5	42.4
Central Illinois	60.3	62.8	43.2	40.9
Average	59.1	65.7	42.4	41.7

TABLE XCVI.—EFFECT OF SEASON ON YIELD AND PERCENTAGE OF GRAIN

Stalks, in. apart	Seasonable 1888–1891		Ears, per cent	Dry 1893–1894		Ears, per cent
	Corn, bu.	Stalks, lb.		Corn, bu.	Stalks, lb.	
11	59.14	4,960	45.5	13.80	4,360	18.1
12	57.81	4,201	49.6	14.28	5,204	16.1
14	57.79	4,158	49.3	19.39	3,762	26.5
16	54.05	4,065	48.2	21.27	3,143	32.2
19½	49.76	3,617	49.1	22.07	3,092	33.3

Mooers (1920) states: "Different varieties (*of corn*) require appreciably different rates of planting. In general the small and short-season varieties require thicker planting than the large, long-season varieties." Professor Mooers found a close relationship between the best rate of planting for grain production and a definite yield of grain per plant.

The proper rate of planting corn may be calculated approximately by the following equation:

$$N = \frac{56Y}{F}$$

In the equation N represents the number of stalks per acre, Y the expectancy or approximate production in bushels per acre and F the standard varietal factor. The standard factor (F) or the average weight of grain per plant at the best rate of planting has to be determined experimentally for each variety.

The equation for land yielding on the average more than 64 bushels per acre, is as follows:

$$N = \frac{56Y}{F + (Y - 64).0014}$$

The equation for land yielding on the average less than 64 bushels per acre, is as follows:

$$N = \frac{56Y}{F - (64 - Y).0014}$$

The last two equations give a somewhat more reliable measure than the first equation. The figure .0014 has been determined experimentally and it is expected to take care of the effect produced on the varietal factor by changes in the productivity of the soil.

Methods of Planting.—Corn may be "surface planted," that is, the land is prepared level and, as a general rule the seed planted from 1 to 3 inches deep. On the wetter lands of the South, ridges are thrown up and made level on top and the corn planted as on unridged land. Corn may also be planted in furrows. This method is used only where the soils have an open structure and where the rainfall is low and is known as *listing*.

Corn may be drilled in rows or planted in check rows; in the latter method, the corn may be cultivated both ways. The seeds may be planted by hand or with machinery. On the market are a number of one-row and two-row planters drawn by one and two horses, respectively.

Hill as Compared with Drill Planting.—These two methods of planting apparently give the same yield of grain, when the same number of stalks are grown per acre. This conclusion has been shown by results secured by Morrow and Gardner (1894) in Illinois, Montgomery (1909) in Nebraska and by unpublished data at the Virginia Experiment Station.

Cultivation.—The subject of cultivation of the corn crop has been discussed in Chapter XV. The recommendations vary to a considerable extent, according to the section of the country in which the crop is grown. The outstanding consideration in the cultivation of corn is the killing of weeds.

The modern one-row and two-row riding cultivators show a marked advance over the old "single shovel" and "double shovel" one-horse cultivators. There are several types of riding cultivators on the market which allow a rather wide selection of implements for various conditions.

Harvesting.—The harvesting of the corn crop and the comparison of the various methods are given and discussed in Chapter XVI. The method of harvesting varies widely in the different sections of the country.

Silage.—The subject of silage has been discussed in Chapter XIX. However, the production of corn for silage differs but little from the production of the crop for grain. The crop is cut somewhat earlier for silage than for grain, there being a difference of about 1 week, if best results are to be expected. Silage corn is usually planted somewhat more thickly than when the crop is to be used for grain. However, if the rate of planting is increased too much, the quality of the silage is lowered,

because of the lower ratio of grain to stalk in the thicker plantings. The results secured by Morrow (1891) in Illinois showed that after a certain thickness of planting is reached, the yield of grain begins to decrease, although the stover continues to increase. Corn is usually drilled when grown for silage.

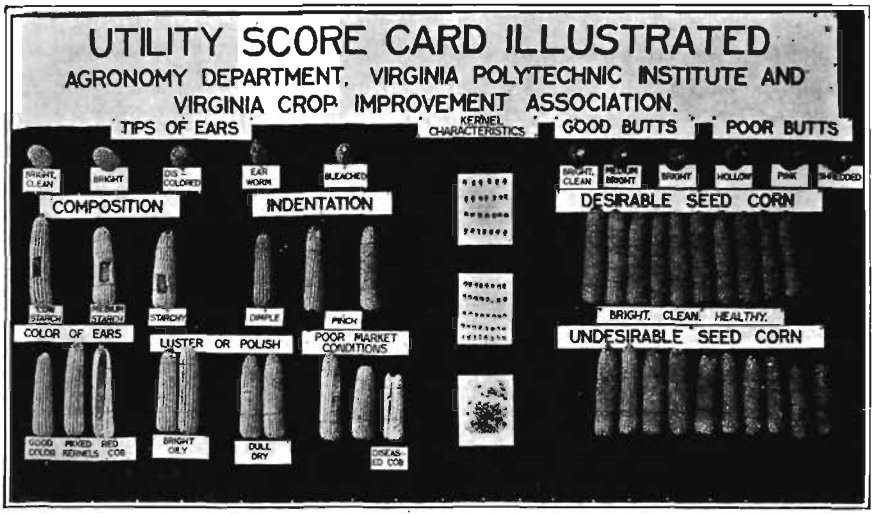

FIG. 46.—Showing desirable and undesirable characteristics of seed corn.

Judging.—The tendency at the present time is to depart to some extent from the old methods used in judging corn. The doubt that has arisen in regard to the old system of judging corn has been created by the results secured by various investigators which indicate that there is apparently little, if any, correlation between many of the score card characters and yield. Recently a number of utility corn shows have been held. The score cards used in these shows stress the importance of those characteristics of the ear thought to materially affect yield, rather than the fancy points which may not be correlated with yield.

SOME INSECT PESTS

Western Corn Root Worm.—The Western corn root worm (*Diabrotica longicornis*) in the adult stage is a beetle about the size of the cucumber beetle (*Diabrotica vittata*), green or yellowish-green in color with black eyes. This pest causes serious injury to corn in the northern Mississippi Valley where corn is grown continuously on the same land. The eggs are laid in late August and in September near the base of the corn stalks and just beneath the surface of the ground. The eggs hatch the following May and June and the larvae attack the roots of the corn plants but never burrow into the lower stems. After the larvae have developed, they

leave the corn plant and build earthen cells in the soil within which they pupate. During late July and August the adult beetles appear and feed on the pollen and silk of the corn plant. They also feed on other plants such as clover, beans and cucumbers.

Control.—Crop rotation has proved very efficient in controlling this pest.

Corn Root Aphis.—The corn root aphis (*Aphis maidiradicis*) causes serious injury to corn east of the Rocky Mountains and especially in the corn belt, where corn is grown continuously on the same land. The aphis is a small, soft-bodied insect about the size of a pinhead, spherical in shape, bluish-green in color and covered with a fine, whitish powder which gives the grayish-green appearance. There are four forms of the aphis. The males and the egg-laying females occur only in the fall. The eggs laid by the females are taken by ants to their nests and kept during the winter. In the spring and through the summer winged and wingless females are produced and these give birth to living young. Through tunnels made by the ants the aphides which hatch from the eggs are carried by ants to the roots of corn plants. These aphides mature in about 15 days and give birth to a second generation. This and the succeeding generation give birth to living young. About 16 generations are produced from spring to fall. The males and egg-laying females begin to appear about the first of October and the eggs are laid and stored by the ants. The ants in return for their activities and attention to the aphides secure a sweetish fluid which is produced by the aphides.

The aphides cluster on the roots of plants, preferably the corn plant, and suck the juice of the plants. The effect on the plant is similar to that of drought and the most noticeable injury occurs while the plants are yet small. The infested plants become dwarfed and the leaves brown and discolored. The plants are seldom killed outright and injury from attacks to the older plants may pass unnoticed. Ant hills are to be found at or near the corn hills affected by the aphides.

Control.—Crop rotation and good cultural methods are very effective in reducing the injury of the aphides. Deep plowing in the late fall and winter and harrowing early in the spring will aid in destroying the ant hills which harbor the eggs of the aphides.

Chinch Bug.—The chinch bug (*Blissus leucopterus*) attacks such crops as corn, wheat, oats, sorghum and millet. It is especially destructive east of the Rocky Mountains and from Manitoba to Texas. The adult is about one-fifth of an inch long and occurs in two forms, one with short wings and the other with long wings. Both forms are white just after emergence from the pupal stage, but soon turn black. The upper wings are whitish at the base and white at the tips, and contain a black spot near the center. The underwings are whitish.

The adults appear in the spring and lay their eggs in the soil about the roots and on the roots and stems of wheat, especially on the lower leaves. During the summer the eggs may be found in connection with corn and the succulent crops. The eggs hatch in 2 to 3 weeks. The nymphs produced often do serious injury to small grains and grasses upon which they become full grown about harvest. When wheat is harvested, they migrate to oats and corn, and the migration takes place on foot although the adults have wings. Eggs are laid upon the unfolding corn leaves and the nymphs begin to emerge in about 10 days. The second brood matures on corn in August and September, and it is this generation which goes through the winter. The adults hibernate over-winter in bunches of grass, in shocks of corn, in corn stubble or under any available rubbish or material along fence rows, ditch banks and so forth.

Control.—In the control of the chinch bug, it is usually necessary to combat it throughout the entire season. The periods of special importance in combating the insects, are in November and early December, when they have just gone into winter quarters; from the appearance in the spring until wheat harvest; and from the time the corn and sorghum crops are harvested until the adults begin to hibernate.

The places of hibernation should be destroyed by burning or plowing under. The migration of the insects to corn or from one field to another can be checked by use of a dust furrow as a barrier. A furrow should be plowed around the threatened field on the sides from which the attack is likely to come and the soil thoroughly pulverized by repeatedly dragging a heavy log in the furrow. The dust will largely prevent the insect from crawling over the steep side of the furrow, which should be next to the threatened crop. Moreover, if holes are made in the furrow at intervals, the insects will accumulate in these holes and may be killed. The furrow may also be made with a groove drag.

The dust furrow is effective only in dry weather; in which case a strip of coal tar may be run around the field. The land may be prepared for the tar by plowing and rolling and by placing the tar strip on the rolled surface. At times it may be advisable to spray the crops to kill the insects on the plants.

SOME DISEASES

Root, Stalk and Ear Rots.—According to Holbert and Hoffer (1920), the rot diseases of the roots, stalks and ears of corn caused losses in 1919 estimated at 125,175,000 bushels, or 4 per cent of the total crop. The root, stalk and ear rot diseases of corn are caused by several fungi. The *Fusarium*, which also causes the scab disease of wheat, is one of the common causes of the disease. The infection occurs chiefly in the roots, the base of the stalk and the ears, but the symptoms may appear in all parts

of the plant. The presence of the disease in the field may be indicated by some or all of the following symptoms, which are grouped for convenience into four stages in the development of the plants.

In the *seedling stage* the presence of the disease may reveal itself by death of the plants, by seedling blight accompanied by infection of roots and lower part of stalks or by yellowing and stunting of seedlings which do not succumb at once. In the *young plant stage*, when the corn is about knee high, the presence of the disease is shown by irregularity in the height of plants, by dead tissue at tips of leaves, by discoloration and rotting of the base of the stalk, rotting of roots and by wilting of diseased plants on hot, dry days. In the *silk and tassel stage* the diseased plants develop tassels and silks about 5 to 10 days later than normal plants, and this development is accompanied by the death of the tassels and tops, by firing of the lower leaves and by leaning of stalks due to the weakened condition of the roots. The symptoms of diseased plants in the *ear stage* are premature death or unduly delayed ripening. The late-maturing stalks may be barren or bear ears varying in size and quality from nubbins to those of full size. Frequently the diseased plants are either leaning or blown down. The disease in the ear stage may be also shown by shank infection. Frequently, the shanks of ears on diseased plants are broken or rotten and the ears hang down. The ears borne by such shanks may be rotten or soggy; or they may ripen but have kernels which are rough, shrunken, starchy or dull in color. The butts of the ears are often shredded and discolored.

Control.—Infection may come from two sources, the seed and the soil. The soil infection is very important where the land is cropped continuously to corn but relatively unimportant when corn is grown only once in a 3- or 4-year rotation. If disease-free seeds are used, the infection from the soil can be reduced by practicing crop rotation and by building up the productivity of the soil. Disease-free seeds can be insured only by using the germination test known as the "modified rag doll test."

Field selection will aid greatly in obtaining disease-free seeds. The best ears are those that ripen early on good, normal, upright stalks which are still green when the husks turn yellow to brown and the ears become firm. The ears should not be borne perfectly erect nor should they hang straight down. The shank should be unbroken and the kernels free from rot. In the dent varieties the kernels should have rather shallow, smooth dents and bright color. The ears should be inspected before making the germination test. Ears on which the shank attachment is discolored or cracked and shredded or those whose kernels are dull in appearance should be discarded. Kernels which are very starchy and have deep, rough dents are undesirable. In the germination test, kernels which show any rotting of the roots or of the inside of the grain should be discarded.

Smut.—Smut (*Ustilago zeae*), a fungus disease of corn, causes an average annual loss of about one-half of 1 per cent of the crop, or about 15,000,000 bushels. The smut masses may be seen on any part of the corn plant—the roots, stalks, leaves, ears and tassels. The smut masses are at first covered with white membranes which later rupture and expose the black, sooty spores. These spores carry the fungus overwinter and produce secondary spores which infect the succeeding crop.

Infection may take place at any time during the growth of the plant. Any young growing tissue of the corn plant from the seedling stage on to near maturity may become infected. As a rule smut does not appear until the plants are about a foot high, and it is most prevalent when the ears are forming. Moisture is necessary for infection and for this reason the disease is often worse in wet seasons. The spores may have remained in the soil from the previous corn crop or they may have been applied in the manure that was made from feeding diseased corn ears or plants.

Control.—No specific or easily applied control methods are known, as in the case of the wheat smuts. Infection may be reduced by rotation of crops and avoidance of infested manure. Strains of corn resistant to smut may be developed. The practice of ensiling corn reduces the amount of smut in subsequent crops, as the spores cannot survive the fermentation processes in the silo. It does not appear that the smut masses are poisonous to cattle since large quantities have been fed to animals without any ill effects.

CHAPTER XXX

Wheat (Triticum sativum)

According to Ball, Leighty, Stine and Baker (1922), wheat is one of the most important crops of the United States for the following reasons:

> (*a*) Many farmers grow it, (*b*) a large acreage of land is annually devoted to it, (*c*) it constitutes an important part of our domestic commerce, (*d*) it contributes a large part of the value of the exports of the nation, and, most important of all, (*e*) it is the national bread crop.

In the United States, on the average, 5.6 bushels of wheat are consumed per person annually.

World Production.—Figure 47 shows the world production of wheat for the 5-year period, 1910 to 1914.

Average Acre Yields.—For the 10-year period, 1910 to 1919, the average acre yield of wheat was, for the United States, 14.8 bushels; Russia, 10.5 bushels; Germany, 28.8 bushels; Austria, 17.7 bushels; Hungary, 18.6 bushels; France, 17.9 bushels; and the United Kingdom, 31.9 bushels.

Production in the United States.—Figures 48 and 49 show the acreages for winter and spring wheats in the United States in 1919.

The average annual yield for the United States as a whole during the 5-year period, 1910 to 1914, was for winter wheat 494,654,000 bushels with an average acre yield of 16.4 bushels; during the period 1915 to 1919 the average annual production was 578,575,000 bushels with an average acre yield of 15.1 bushels. For spring wheat during these periods the average yield was 233,571,000 and 259,063,000 bushels, respectively, with average acre yields of 12.4 and 12.8 bushels.

The six states, Kansas, North Dakota, Nebraska, Oklahoma, Illinois and Washington, produced 425,039,000 bushels of wheat, or 51 per cent of the entire crop in 1920. The entire crop of North Dakota is spring wheat, while that of Oklahoma is winter wheat. The other four states grow both winter and spring wheat, but the winter wheat predominates.

Historical.—The origin of wheat is not known, as the cultivation of the crop is older than the history of man. The finding of wheat in certain monuments shows it was cultivated before the Hebrew Scriptures were written. Wheat is first mentioned in the Bible in Genesis, Chapter 30, verse 14. The lake dwellers of Switzerland cultivated wheat in the Stone Age. Chinese history shows that wheat was grown 2700 B.C., and it was one of the five kinds of seeds sown in their annual ceremony.

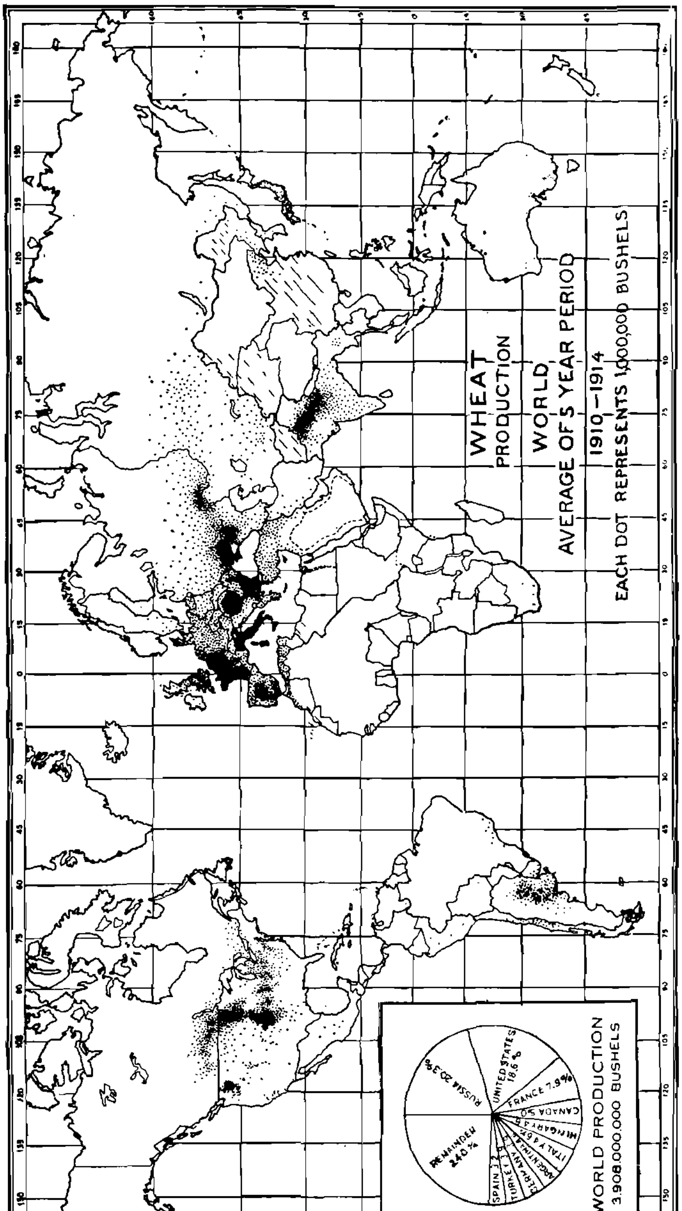

FIG. 47.—World wheat production before the war. Russia was then the greatest producer in the world and the United States was second. No satisfactory statistics of production since the war are available from some important producing countries. The North Temperate Zone produces most of the world's wheat. (*U. S. Dept. Agr. Yearbook*, 1921).

The many names for wheat given in the ancient languages indicate that the existence of the crop dates back to remote times.

The geographical origin of wheat is in doubt. It is thought by some to have originated in Mesopotamia. According to DeCandolle, wheat once grew wild in the Euphrates and Tigris valleys and from there spread to the rest of the world.

Wheat was not grown in America until after the discovery of the New World by Columbus but the production started on the Atlantic Coast in

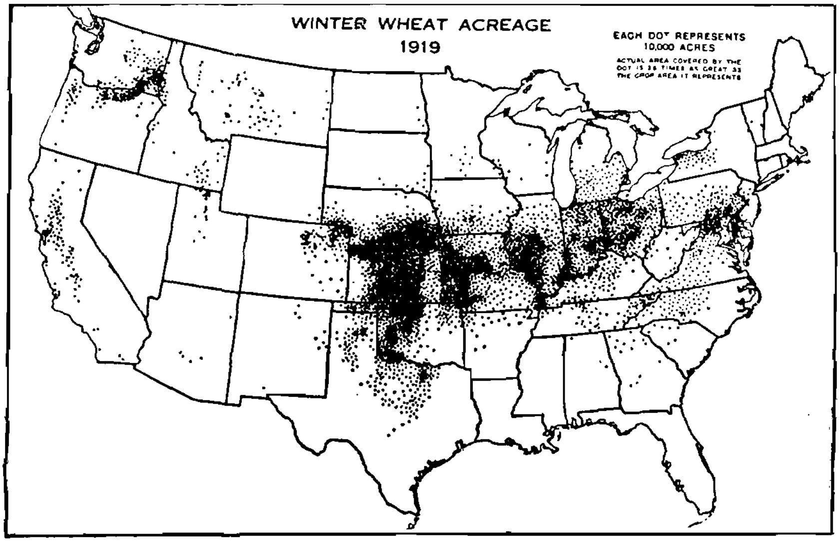

FIG. 48.—The corn and winter wheat belt included 42 per cent of the nation's acreage of winter wheat in 1919, and 30 per cent more was located in the southern and eastern portions of the corn belt. The southern boundary of this winter wheat belt follows the isotherm of 72 degrees during the month preceding harvest (June 15); and, although some wheat is grown south of this line, it frequently suffers severe damage from rust. The northern frontier of winter wheat follows, in a general way, the mean winter temperature line of 20 degrees, which extends in a northwesterly direction from northern Illinois and Iowa diagonally across South Dakota and Montana. (*U. S. Dept. Agr. Yearbook*, 1921).

the Virginia Colony at least as early as 1618. The production moved westward with the settlement of the country. In 1839 the wheat crop of the United States amounted to 84,823,272 bushels. At this time New York, Pennsylvania, Virginia and Ohio produced 60 per cent of the crop. By 1859 wheat production had moved rapidly westward and in 1919 the total production for the country was 945,403,215 bushels.

The biological origin of wheat is not definitely known. The grain is believed by some to have come from *Aegilops ovata*. This plant grows wild in abundance in southern Europe and bears one grain per head. Cook (1913) reports wheat growing wild in Palestine similar in many respects to cultivated wheat.

Classification.—According to Clark, Martin and Ball (1922, page 49), after Hackel, there are in cultivation eight groups or types of wheat. They are as follows:

- *Triticum*
  - *sativum*
    - *tenax*
      - *vulgare Vill.*, Common wheat
      - *compactum Host.*, Club wheat
      - *turgidum L.*, Poulard wheat
      - *durum Desf.*, Durum wheat
    - *dicoccum Schr.*, Emmer
    - *spelta L.*, Spelt
  - *polonicum L.*, Polish wheat
  - *monococcum L.*, Einkorn

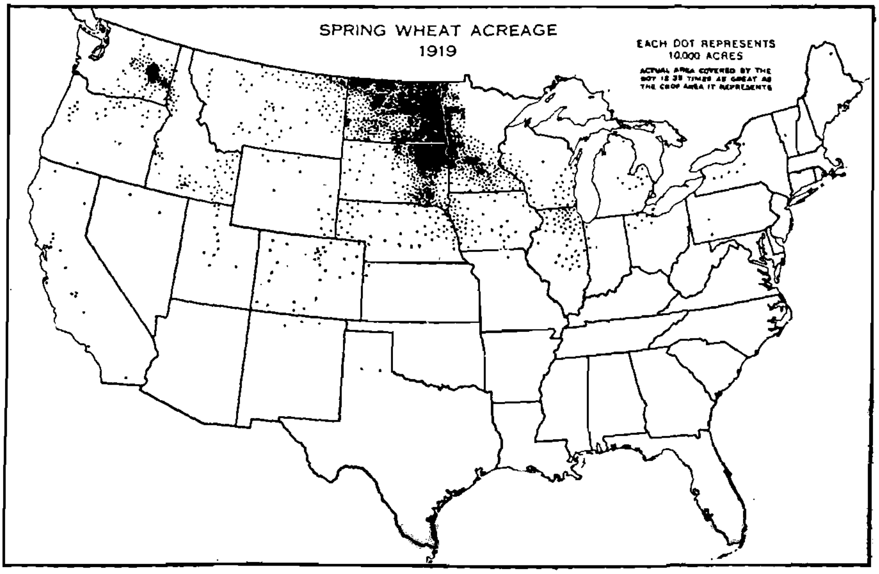

Fig. 49.—About half the acreage of spring wheat in 1919 was in the spring wheat area, where it constituted 40 per cent of the acreage of all crops, and most of the other half was located in the adjoining portion of the Great Plains region. A secondary but important center of production is located in the subhumid portions of Washington and Oregon. The southern boundary of the spring wheat area is determined largely by the northern boundary of winter wheat, which is, in general, more productive and more profitable where it can be grown. The northern limit of spring wheat is approximately the mean summer temperature of 58 degrees, which is found in the United States only in the western mountains. (*U. S. Dept. Agr. Yearbook*, 1921).

Einkorn, as the name implies, has one kernel to the spikelet. It is supposed by some to be the most primitive type of wheat, and is not cultivated in America.

Emmer has two kernels to the spikelet, one being located somewhat above the other. The kernels are hard, red, compressed and remain in the chaff in threshing. There are winter and spring varieties, all of which are awned. The best known varieties are the black winter and the white spring emmers. Emmer seems to be hardy and will pro-

duce a fair crop under adverse conditions of soil and climate. The stems are usually pithy. The crop is used for feed in this country.

Spelt usually bears two kernels to each spikelet. They are light red in color, somewhat compressed, narrow and furrowed. The walls of the kernels are flattened and have sharp edges. Since the spike is very brittle, the rachis is broken into pieces in threshing and the kernel is held in the chaff. Spelt may be distinguished from emmer by

FIG. 50.—Polish wheat and Einkorn; glumes from lower, central and upper portions of spike. (*U. S. Dept. Agr., Cereal Investigations*).

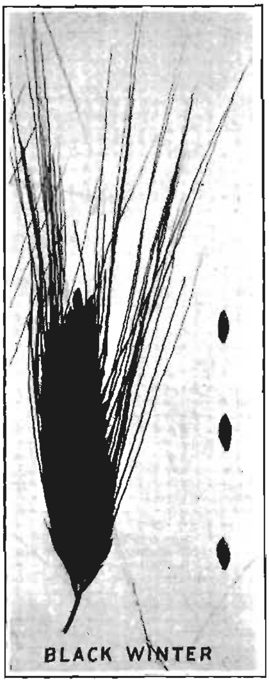

FIG. 51.—Black winter emmer; glumes from lower, central and upper portions of spike. (*U. S. Dept. Agr., Cereal Investigations*).

the character of the pedicel of the spikelet. In the former the pedicel is blunt and thick, while in the latter it is short and pointed. Also, emmer spikelets are flattened on the inner side instead of being convex as in spelt. Therefore, the emmer spike is more compact than the spelt. There are both winter and spring varieties of spelt as well as bearded and beardless types, and the production is not great in this country

Common wheat is extensively grown in this country and about 85 per cent of the acreage is seeded to this wheat. The spikelets usually contain two or three kernels, but sometimes four or more. They vary in color from white to dark red, and fall from the chaff in threshing. There

are a number of both winter and spring varieties grown, including both bearded and beardless forms. The head is broad in the plane of the rows of spikelets, narrow on the sides between the rows and usually tapers toward the apex. The stems are generally hollow but sometimes may be slightly pithy. These wheats are used largely for bread making.

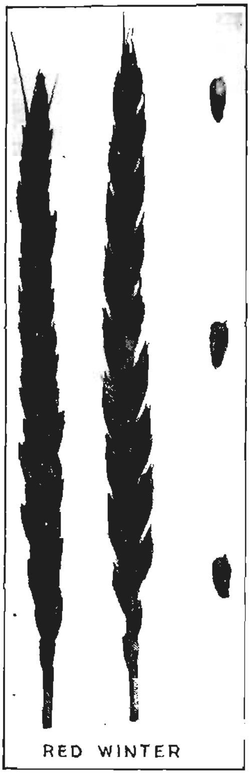

Fig. 52.—Red winter spelt; glumes from lower, central and upper portions of spike. (*U. S. Dept. Agr., Cereal Investigations*).

Club wheat comprises about 7 per cent of the wheat acreage of the country. The spikelets contain from three to five kernels and at times practically all contain four. The kernels are usually short and small, occasionally round, frequently boat-shaped, white to red in color, but usually white; they fall from the chaff in threshing. The kernels remain in the chaff well and the crop may be left standing in the field after ripening without loss from shattering. There are both spring and winter varieties, but more of the former. There are both bearded and beardless varieties. The spikes are usually very short, thicker at the apex than at the base and frequently 4-sided. The spikelets fit very close together, and thus give a compact spike. The culms are short, stiff and erect. These wheats are used for making crackers and starchy breakfast foods; and in some localities the flour is used for bread making.

Poulard wheat is not grown to any great extent in the United States. The kernels are large, proportionally short and usually boat-shaped, somewhat hard, light yellowish-red, sometimes nearly white in color and often vitreous. These wheats are closely related to the durum group. The spikes are long, often 4-sided, compact and awned. The culms are stiff, thick and sometimes pithy.

Durum wheat includes about one-sixteenth of the total wheat acreage of the country. The kernels of these wheats are the hardest known and for this reason are often called "hard" wheats. The spikelets contain two to four kernels. The kernels are long, very hard in fracture, sometimes translucent and vitreous, and amber in color with sometimes a tendency to reddish; they fall from the chaff in threshing. Practically all the varieties are suitable only for spring sowing. The spikes are compact, usually rather slender and always bearded. These wheats are used for flour, but largely for macaroni, spaghetti, vermicelli and other edible pastes.

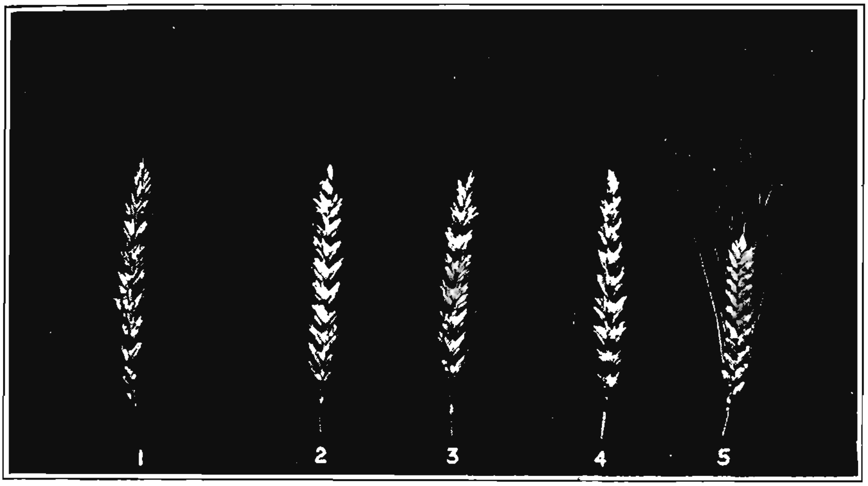

FIG. 53.—Common (hard spring) wheats. Left to right: Turkey, Power, Preston, Haynes Blue Stem and Kubanka. The first four are common wheats, while Kubanka is a durum. (*U. S. Dept. Agr., Cereal Investigations*).

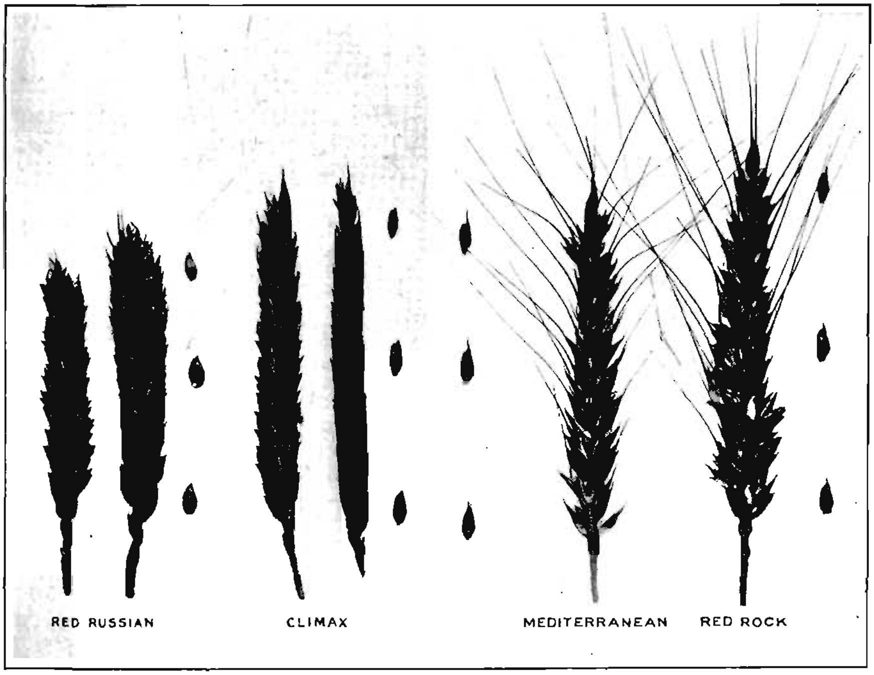

FIG. 54.—Common (soft red winter) wheats; glumes from lower, central and upper portions of spike. (*U. S. Dept. Agr. Bul.* 1074).

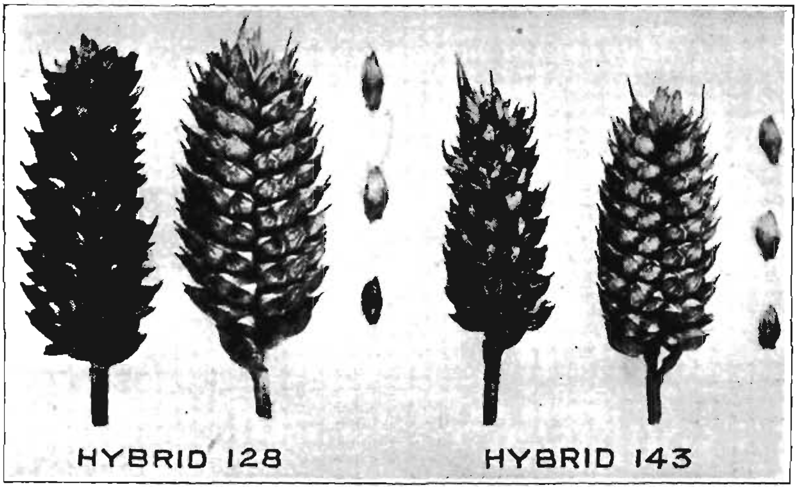

FIG. 55.—Club wheats, face and side views; glumes from lower, central and upper portions of spike. (*U. S. Dept. Agr. Bul.* 1074).

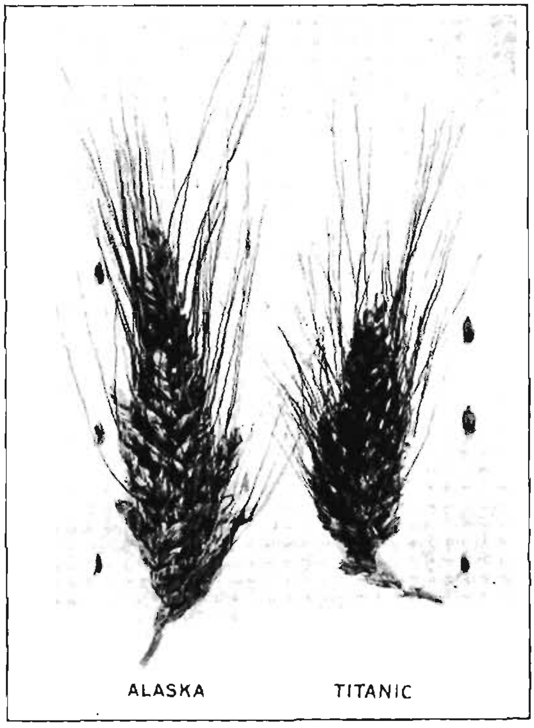

FIG. 56.—Poulard wheats, side view; glumes from lower, central and upper portions of spike. Alaska on left and Titanic on right. (*U. S. Dept. Agr. Bul.* 1074).

Polish wheat is also called Giant rye, Astrakhan wheat, Jerusalem rye and Montana rye. It is not grown extensively in the United States. The kernels are very large, proportionally long, yellowish-white in color and very hard. There are several varieties but the best known one in this country is the White Polish. The spikes are very large, loosely formed, bluish-green in color before ripening and bearded. The glumes are long, narrow, papery in structure and they stand out from the spike, a condition peculiar to these wheats. They are not suitable for bread making, but are adapted for use in the production of macaroni.

Wheat Regions.—The common and club wheats are sometimes called bread wheats. The common bread wheats may be divided into hard

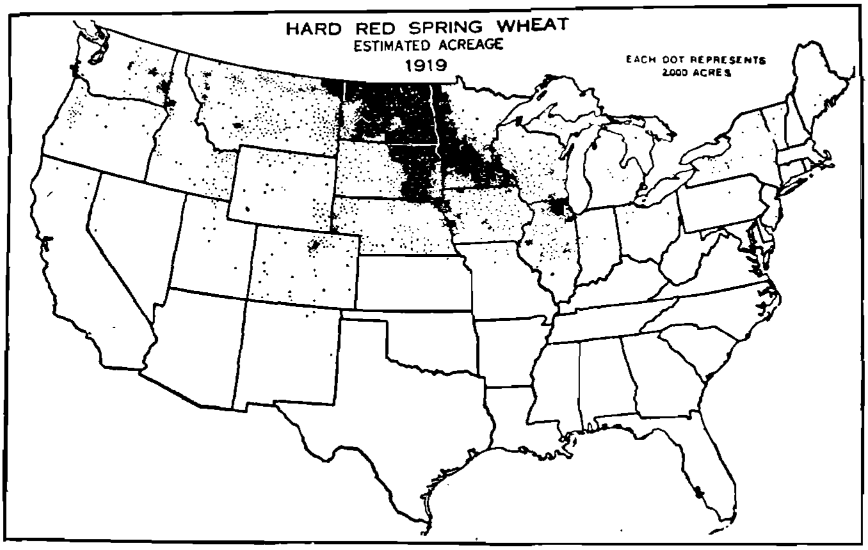

FIG. 57.—More than two-thirds of the spring wheat of the United States belongs to the class of hard red spring wheat, which is grown under subhumid to semi-arid conditions favorable to high quality. North Dakota, Minnesota and South Dakota lead in its production. It sets the standard for bread-making flour. (*U. S. Dept. Agr. Yearbook*, 1921).

red spring, hard red winter and soft red winter. The club wheats may be divided into common white and white club. These two latter classes have now been combined into one in the list of market grades.

The distribution of these wheats as to production areas is shown in Figs. 57 to 62.

The *hard red spring* wheat is grown mainly in North Dakota, Minnesota and South Dakota. This is the standard wheat for bread making flour. It comprises more than two-thirds of the spring wheat of the country and is especially adapted to subhumid and semi-arid climates.

The *hard red winter* wheat is grown extensively in the central section of the Great Plains area. It occupies about one-third of the total acreage

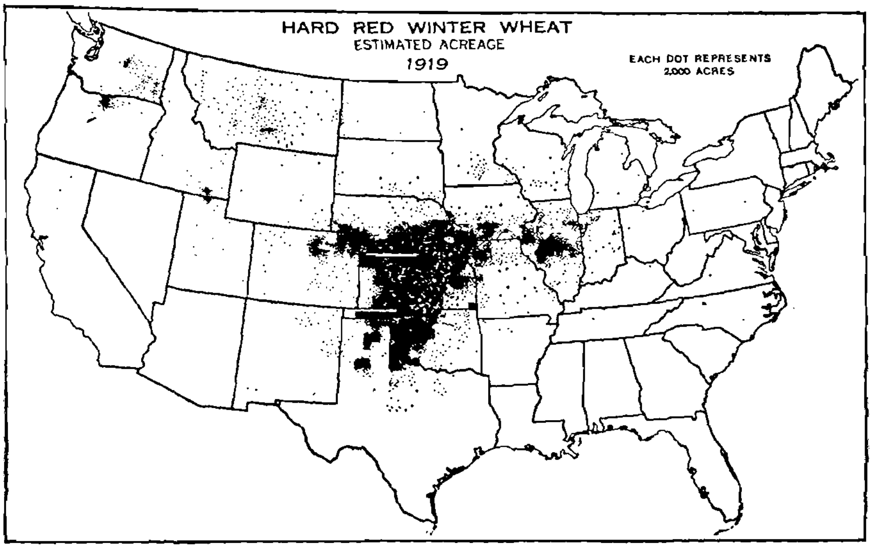

Fig. 58.—Hard red winter wheat is produced in enormous quantities in the central section of the Great Plains area. It occupies nearly one-third of the total acreage of all wheat and about half of the total winter wheat acreage in the United States. Wheat of this class ranks next to hard red spring in quality for flour manufacture. (*U. S. Dept. Agr. Yearbook*, 1921).

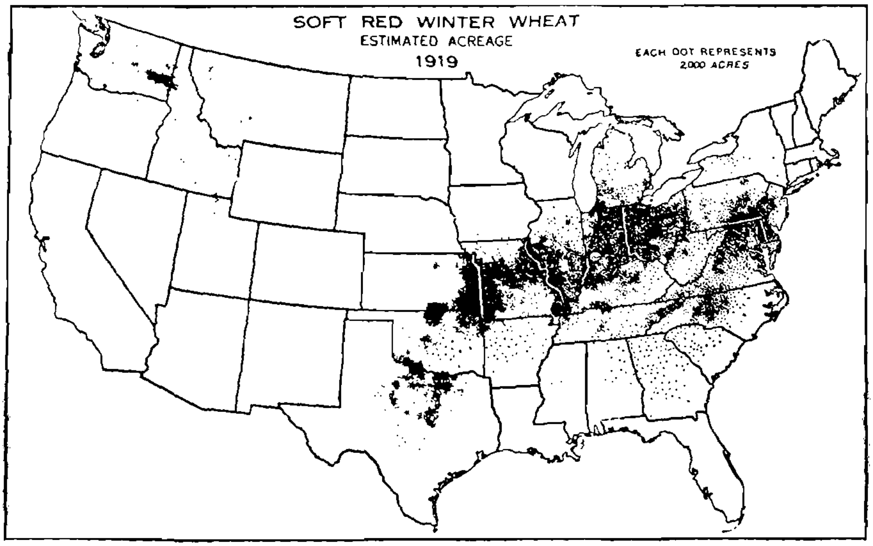

Fig. 59.—Soft red winter wheat is grown over a wide area, mostly under humid conditions. It also occupies nearly one-third of the total acreage of all wheat and nearly one-half of the total acreage of winter wheat. The states leading in its production are Missouri, Indiana, Ohio and Illinois. (*U. S. Dept. Agr. Yearbook*, 1921).

of the country, and about one-half of the total winter wheat acreage. In quality, as a bread wheat, it ranks second only to hard spring wheat.

The *soft red winter* wheat is grown mostly under humid conditions. It occupies about one-third of the total wheat acreage of the United States and nearly one-half of the total acreage of winter wheat. The leading producing states are Missouri, Indiana, Ohio and Illinois. The crop is used in the manufacture of both bread making and pastry flours. The flour is often used for blending with the flour from hard red spring and hard red winter wheats.

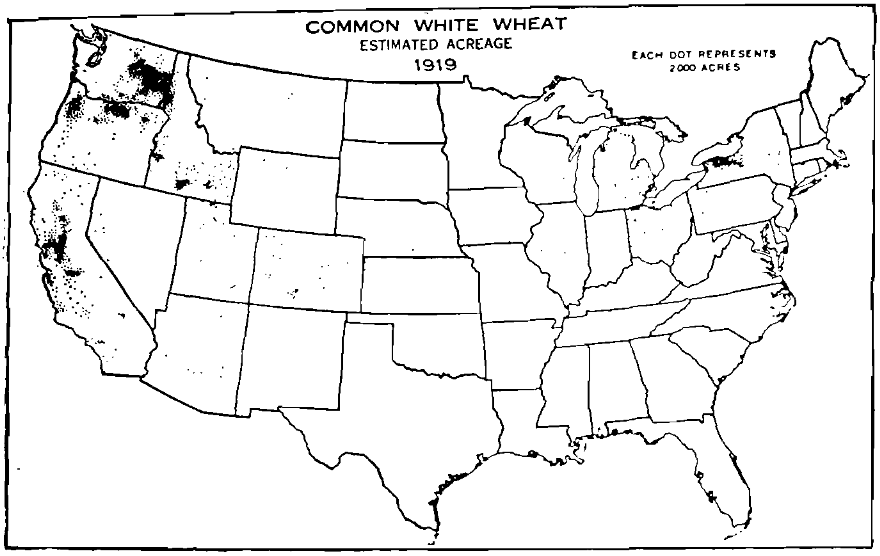

FIG. 60.—*Common white wheat is grown chiefly in the Far West, but also in the Great Lakes section. Washington, California, Oregon and Idaho lead in its production in the West; New York and Michigan in the East.* (*U. S. Dept. Agr. Yearbook*, *1921*).

The *common white* wheat is grown chiefly in the Far West, but to some extent in the Great Lakes region. About 5 per cent of the total wheat acreage is planted to this class. In the West, Washington, California, Oregon and Idaho lead in production; in the East, New York and Michigan lead in production. The crop is used to some extent for bread making flour, but usually for making pastry flours and breakfast foods.

The *white club* wheat is grown only in the West, mainly in Washington, Oregon, California and Idaho. Less than 2 per cent of the total wheat acreage is planted to this class. The white club wheat is used for making starchy flours for pastry or for export to South America and to the Orient.

The *durum* wheat is grown in the hard red spring wheat area. It is resistant to drought and black stem rust, and the center of production

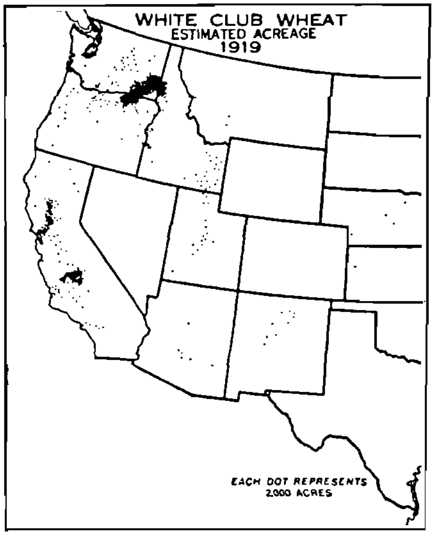

Fig. 61.—White Club wheat is grown only in the West, chiefly in Washington, Oregon, California, and Idaho. (*U. S. Dept. Agr. Yearbook*, 1921).

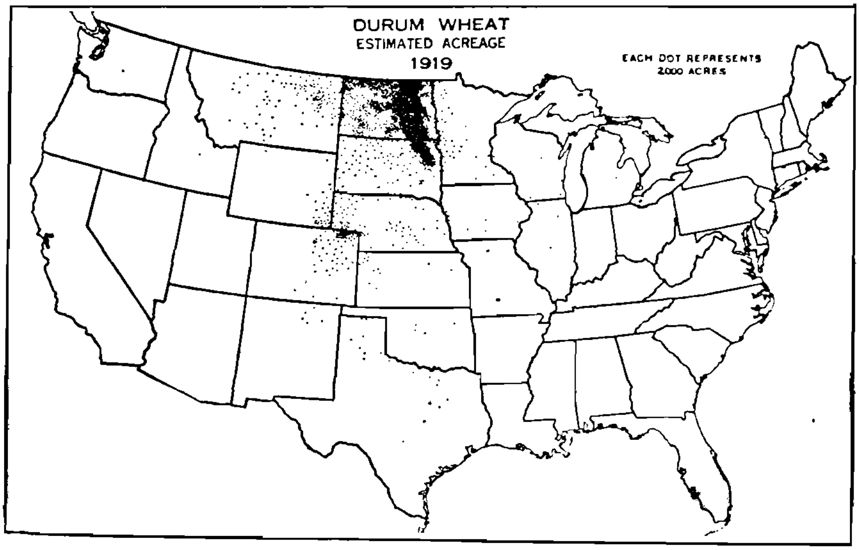

Fig. 62.—Durum wheat is grown in the midst of the hard red spring wheat area. The center of the area of production gradually is moving westward to drier districts. From durum wheat is made a granular flour called "semolina," from which macaroni, spaghetti, vermicelli and other edible pastes are manufactured. (*U. S. Dept. Agr. Yearbook*, 1921).

is gradually moving westward to drier districts. The greatest production of durum wheat is just west of the Red River Valley in North Dakota. As has been previously stated, about one-sixteenth of the total wheat acreage is planted to durum wheat and the crop is used largely for making macaroni, spaghetti and other edible pastes. However, some of the crop is made into flour for blending with the softer wheats.

Hard and Soft Wheats.—As a rule the hard wheats are dark in color, while the soft wheats are pale. In fracture the hard wheats are dark and vitreous in structure and show no white starch. On the other hand, the soft wheats possess a white, starchy interior.

The soft wheats are lower in gluten than the hard wheats, make a "weak" flour and are preferred for making biscuits, crackers, pies and starchy breakfast foods. The hard wheats are higher in gluten than the soft wheats and make a "strong" flour. The hard wheats are especially desirable for bread making. The strength of flour depends largely upon the gluten it contains, which gives to bread its elastic quality and its ability to absorb water. Gluten may be removed from dough by washing with water. A good quality gluten is pale yellow in color, tenacious and elastic; gluten of poor quality is dark-colored, tenacious, but not elastic.

Varieties.—There are a large number of varieties of wheat, about 1,000 having been collected by the United States Department of Agriculture up to 1895. Many of these varieties are not adapted to American conditions and less than 200 were considered of merit. It is not practicable to attempt to name the varieties best suited to all sections of the country. The variety of wheat best suited for particular conditions should be determined by trial. Such tests are being conducted by the various experiment stations of the country.

In the hard red spring wheat class, 24 varieties are found but two-thirds of the acreage of this class is seeded with Marquis. The leading varieties of hard red winter wheat are Turkey, Kharkof and Kanred. There are in all about 65 varieties of soft red winter wheat, but the principal varieties are Fultz, Fulcaster, Mediterranean, Poole, Red May and Red Wave. In the case of the common white wheat, more than 56 varieties are grown, the leading varieties being Pacific Bluestem, Goldcoin, Baart, Defiance, Dicklow and Dawson (Golden Chaff). There are 11 commercial durum wheats grown but Arnantka and Kubanka are the leading varieties.

Uses.—Most of the wheat crop produced in the United States is consumed within the country. A small percentage of the crop is used for seed; a varying quantity is exported; and the remainder, which is also variable, is held in the country to carry over from year to year. The disposal of the crop is shown graphically in Fig. 63. On the per capita basis, consumption is increasing and production and exports are decreas-

ing. During 1839 to 1849 the per capita consumption was 80.9 per cent of per capita production; in 1875 to 1884, 58.3 per cent; and in 1905 to 1914, 71.8 per cent.

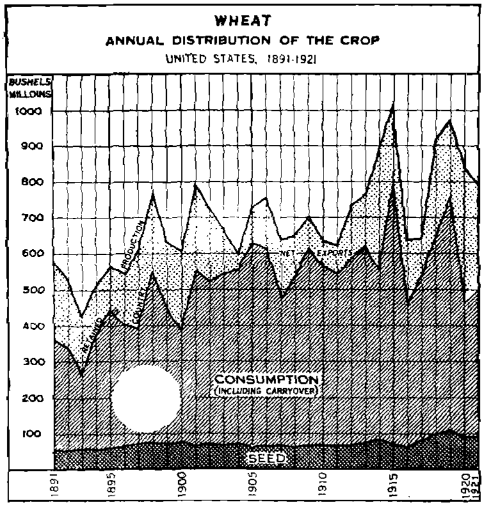

FIG. 63.—*Disposal of the American wheat crop during the last 30 years.* (*U. S. Dept. Agr. Yearbook*, 1921).

The bulk of the wheat used in this country is made into flour. Among the by-products of wheat may be mentioned bran, shorts and middlings; and these milling by-products of wheat constitute about 25 per cent of the wheat used as feed.

CULTURE

Seed.—It is of great importance to use high-yielding strains of good varieties of wheat if maximum yields are to be expected. Since wheat plants are self-fertilized, it is to be expected that they will tend to remain uniform in yielding capacity, provided they do not become mixed through mechanical means such as the itinerant threshing machine. If it becomes necessary to change seed wheat, the new seed selected should be of proved merit and known to be adapted to the region in which the crop is to be planted.

It is also good practice to grade wheat with the fan mill, or seed cleaner, in order to remove the diseased and very chaffy seeds, and weed seeds. Most of the results in comparing light and heavy seed, as separated by the fan mill, show but slight difference in yield. However, as shown in Chapter VIII, when the difference in size of seeds is great enough, the large seeds give higher yields than the small seeds.

Time of Seeding.—The proper time of seeding wheat in the fall depends upon several conditions, especially the likelihood of winter-killing

and attacks from the Hessian fly. The proper time of seeding winter wheat in reference to Hessian fly injury is shown in Fig. 64.

Spring wheat is usually sown as early as practicable in the spring. The time of seeding both winter and spring wheats is shown in Chapter XIV.

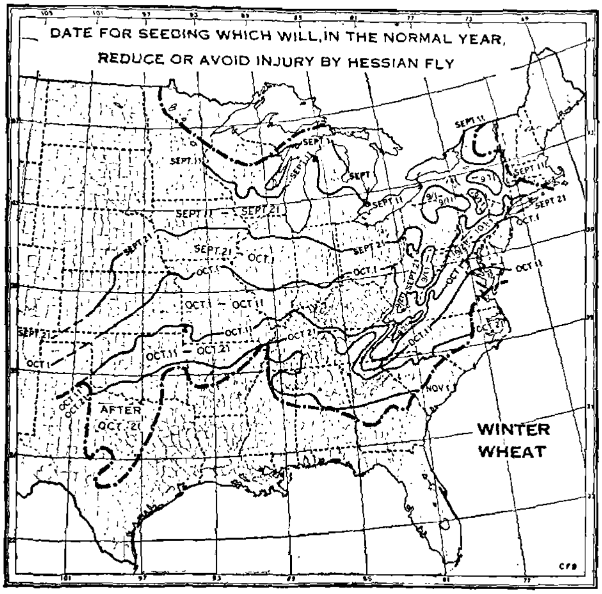

Fig. 64.—In the area infested by Hessian fly, wheat seeding must be delayed until the adult flies have died, or severe injury may result. This fly-free date may be later than the most favorable date for seeding wheat from other viewpoints. (*U. S. Dept. Agr. Yearbook,* 1921).

Hutcheson (1908) in Virginia found, as an average of the results of 4 years, that winter wheat seeded on September 15, yielded 15.2 bushels; on September 30, 20.2 bushels; on October 15, 16.8 bushels; and on October 30, 10 bushels. Jardine (1916) found under Kansas conditions that wheat seeded September 30 yielded more than that seeded earlier or later. Williams and Welton (1911) in Ohio report that the largest yield of wheat, as compared with the yields of earlier and later dates, is obtained from seeding on September 21.

These results show that the best time of seeding will vary with conditions.

Rate of Seeding.—It is to be expected that the rate of seeding will vary under different conditions. The amount of seed required for maximum yield will depend upon several factors.

Jardine (1916) found in Kansas the rate of seeding to vary with the date of sowing. Early sowings required less seed than later seedings. When the crop was seeded on September 22, the yield from sowing ½

bushel per acre was 35.62 bushels, while from the 2-bushel sowing the yield was 34.42 bushels. When the crop was seeded on October 28, the yields from the ½- and 2-bushel seedings were 13.16 and 26.66 bushels, respectively.

Under Virginia conditions, according to Hutcheson and Wolfe (1917), on land producing less than 20 bushels of wheat, the seed should be sown at the rate of 1¼ bushel per acre; on land producing more than 20 bushels of wheat per acre, the rate of seeding should be 1 bushel per acre.

Williams and Welton (1911) recommended 2 bushels of wheat per acre for Ohio conditions. The rate of seeding was varied from 3 to 10 pecks per acre; and in all, eight varieties were grown. A summary of their results is given in Table XCVII.

Table XCVII.—Effect of Rate of Seeding Wheat in Ohio

Pecks of seed per acre....	3	4	5	6	7	8	9	10
Average yield per acre, bu.	23.7	25.0	25.7	26.7	26.9	27.8	28.0	27.5
Net yield when seed is subtracted, bu.	23.0	24.0	24.4	25.2	25.1	25.8	25.7	25.0
Average weight per bushels, lb.	58.7	58.8	58.7	58.9	59.0	58.9	59.0	59.1

Depth of Seeding.—The depth at which wheat should be sown will vary with the conditions. The kind of soil, moisture, preparation of the seedbed and other factors will modify the results. Wheat may be seeded deeper on a sandy soil than on a clay soil.

Morrow and Gardner (1892*a*) in Illinois seeded wheat to 1-, 3- and 5-inch depths. The yields from the first two depths were about the same, but the yield from the deepest seeding was considerably less.

Hays (1894) found in Minnesota that wheat planted three-quarters of an inch deep gave the largest yield of straw, while that planted 3½ inches deep gave the highest yield of grain. Plantings were made three-fourths of an inch, 1½, 2½ and 3½ inches deep.

Hickman (1890*a*) found in Ohio that wheat seeded to the depth of 2 inches gave the highest yields. Depths of 3 and 4 inches were unsatisfactory, as was also the ½-inch depth. It seems that the proper depth for seeding wheat is about from 1 to 3 inches.

Broadcast Sowing Compared with Drilling.—Practically all of the wheat sown in this country is drilled. The reasons usually given for drilling are that better germination and less winter-killing result. Drilled seeds are more uniformly covered with soil to the proper depth and the

ridges made by the drill bring about conditions more favorable to the reduction of winter injury.

Burnett (1912) in Iowa found that drilled wheat, based on a 4-year average, yielded 4.2 bushels more than wheat sown broadcast. During these years there was practically no winter-killing. It was stated that the plants on the broadcasted plats would have been more susceptible to winter-killing than the plants on the drilled areas. Salmon (1916) found under Kansas conditions that wheat planted in furrows yielded

Fig. 65.—A good field of soft red winter wheat.

about the same as the surface (drilled) seeded wheat. However, in the case of oats and barley, the crops drilled in furrows yielded more than the drilled crops. The wheat crop is less susceptible to winter-killing in Kansas than either oats or barley. Montgomery (1908) in Nebraska found in dry years that drilling had a decided advantage over broadcasting wheat.

Latta (1889) at the Indiana Experiment Station, found a 4-year average increase of 7.47 bushels in favor of drilling. In another test Latta (1888) found the increase in favor of drilling to be 8.4 bushels.

In South Carolina, Newman and Conner (1898) found, as a result of 1 year's work, that some varieties of wheat gave higher yields when broadcasted than when drilled. With other varieties, however, these investigators found that the reverse was the case, and that the drilled plats germinated more uniformly.

The seed treatment usually followed is the use of copper sulphate (bluestone) or formaldehyde. Where the soil is infected, the use of copper sulphate, according to Heald and Woolman (1915), gives better results. In the eastern part of the United States the formaldehyde treatment is more widely used. In any method of seed treatment the grain should be thoroughly fanned to remove as many smut balls as possible before treatment.

In the *formaldehyde treatment* the seeds are dipped for about 10 minutes in a solution containing 1 pint of formalin (40 per cent formaldehyde) to 30 or 40 gallons of water; or the seeds may be sprinkled with the solution and thoroughly mixed. In case of sprinkling, 1 gallon of the solution will be sufficient for 1 bushel of seed. After treatment by sprinkling or dipping, the seeds should be covered and allowed to remain for several hours or overnight, when they may be seeded or spread out to dry.

A modification of the above method is called the "formalin dry method." It consists in mixing equal quantities of formalin (40 per cent formaldehyde) and water and spraying a small quantity of the solution on each shovelful of grain as it is moved from one pile to another. One quart of the solution is sufficient for treating 50 bushels of grain. After treating, the seeds are covered for 5 hours, when they may be sown or stored.

When the *copper sulphate treatment* is used, a solution of 1 pound of copper sulphate and 1 pound of common salt to 5 to 10 gallons of water is made and the seeds are soaked, sprinkled or dipped. The treatment should be followed at once by dipping or sprinkling with milk of lime (1 pound of quick lime to 10 gallons of water). The seeds should be spread out at once and stirred occasionally to hasten drying.

Loose Smut.—Loose smut is caused by the fungus *Ustilago tritici.* In place of the normal head, a black, sooty mass is produced which consists of the spores of the fungus. The spores may be blown or washed off and the naked rachis left. Infection of the plant takes place at blooming time. The spores from the diseased heads are often carried into the open flowers of healthy heads and lodge on the stigmas. Here the spores germinate and penetrate the embryo without destroying it. As the grain ripens the fungus ceases to grow and lies dormant within the dormant grain. When the grain starts to germinate, the fungus renews its growth, develops with the wheat plant and transforms the flowers of the plant into the sooty spore masses. Thus, the significant points in the development of the fungus are as follows: (1) Infection takes place only through the open flowers of the blooming wheat head; (2) the fungus is carried from harvest to seeding time inside the grain; (3) when the infected seeds are planted, they produce diseased heads which carry the spores of the fungus.

Control.—The treatment most widely used for controlling loose smut is the modified hot water treatment. This treatment will control both the bunt and loose smuts, while the chemical treatments are effective only in case of stinking smut. When the modified hot water treatment is used, the grain should be soaked in cold water for from 4 to 6 hours, and then dipped into hot water at about 120° F. The grain is then soaked for

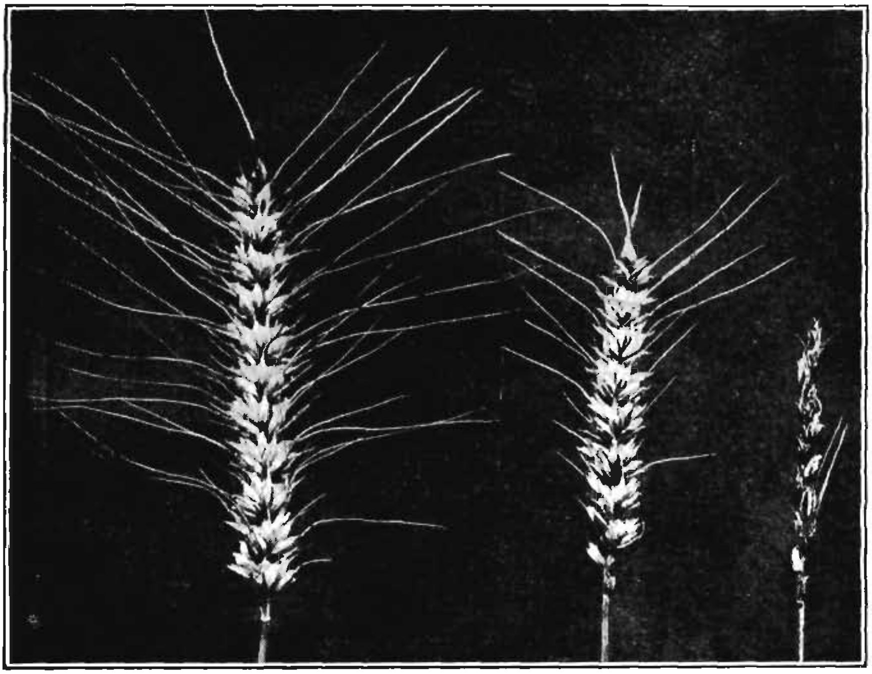

FIG. 66.—Left to right: normal head, stinking smut infection and loose smut infection. All the heads are of the Fulcaster variety of wheat.

10 minutes in water at 129° F. The water must be held as close to this point as possible; the temperature should not be allowed to rise above 131° F. or fall below 125° F. The grain should then be spread out to dry on a clean surface. The seeds may be sown as soon as they are sufficiently dry to run through the drill, the rate of seeding being increased to allow for the swelling; or they may be stored when thoroughly dry. The fact that the treatment sometimes lowers the germination should be taken into consideration when seeding.

Black Stem Rust.—The black stem rust caused by the fungus *Puccinia graminis* affects wheat, oats, barley, rye and about 50 cultivated and wild grasses. In the case of wheat this disease is usually more serious on spring than on winter wheat, but it is sometimes more destructive on winter wheat.

The fungus attacks the stems and leaf sheaths but seldom the blades. There are two stages on the grains; the "red rust" or summer stage, and the "black rust" or winter stage. The red rust stage occurs on the younger growing plants, while the black rust stage appears later on the older plants, straw and stubble. The disease is carried by the wind to the grain crops from its alternate host, the common barberry (*Berberis vulgaris*). It may also pass to the cereals from some grasses such as wild barley, slender wheat grasses, western wheat grass and the wild rye grasses. The fungus seldom lives through the winter on the living cereal host except in the extreme South.

Control.—In the control of the black stem rust disease, the greatest factor is the eradication of the common barberry as shown by results in this country and in Denmark.

CHAPTER XXXI

OATS (Avena sativa)

The oat is one of the most important grain crops in the United States, ranking next to corn and wheat in acreage and crop value. In 1919 oats, as compared with the other crops, ranked fourth in acreage and fifth in value. Notwithstanding these facts, too little attention is given to the production of the crop. The farmer can increase production by using good seed of suitable varieties, seeding early with a grain drill on a well-prepared seedbed, harvesting at the proper time, properly caring for the harvested crop and clean threshing. The crop is best suited to cool, moist climates.

World Production.—Figure 67 shows the world production and acreage of oats during the 5-year period, 1910 to 1914.

Average Acre Yield.—The average acre yield for the 10-year period, 1910 to 1913, was, for the United States, 32.1 bushels; Russia, 22.2 bushels; Germany, 47.5 bushels; Austria, 29.3 bushels; Hungary, 34.8 bushels; France, 32.8 bushels; and the United Kingdom, 43.1 bushels.

Production in the United States.—Figure 68 shows the acreage of oats in the United States for 1919.

The average annual yield for the United States as a whole for the 5-year period, 1910 to 1914, was 1,157,961,000 bushels, with an average acre yield of 30.5 bushels; during the period 1915 to 1919 the average annual production was 1,423,152,000 bushels and the average acre yield was 33.7 bushels.

The six states, Iowa, Illinois, Minnesota, Wisconsin, Nebraska and Indiana in 1920 produced 807,677,000 bushels of oats, or 54 per cent of the entire crop.

Historical.—The origin of the oat, like that of the wheat, is not definitely known. It probably originated in a temperate climate, in eastern temperate Europe or western Asia. It was apparently unknown to the ancient Egyptians, the Hebrews, the Greeks, the Romans, the Chinese and the people of India, as these people did not cultivate this crop. It was cultivated by the prehistoric peoples of central Europe but probably not until after the cultivation of wheat and barley.

It is believed that oats were not grown in America until after the discovery by Columbus. The crop was grown by the early colonists. In 1839, 123,071,341 bushels were produced in the United States; in 1909, the production amounted to 1,007,142,980 bushels; while in 1920, the production was 1,496,281,000 bushels.

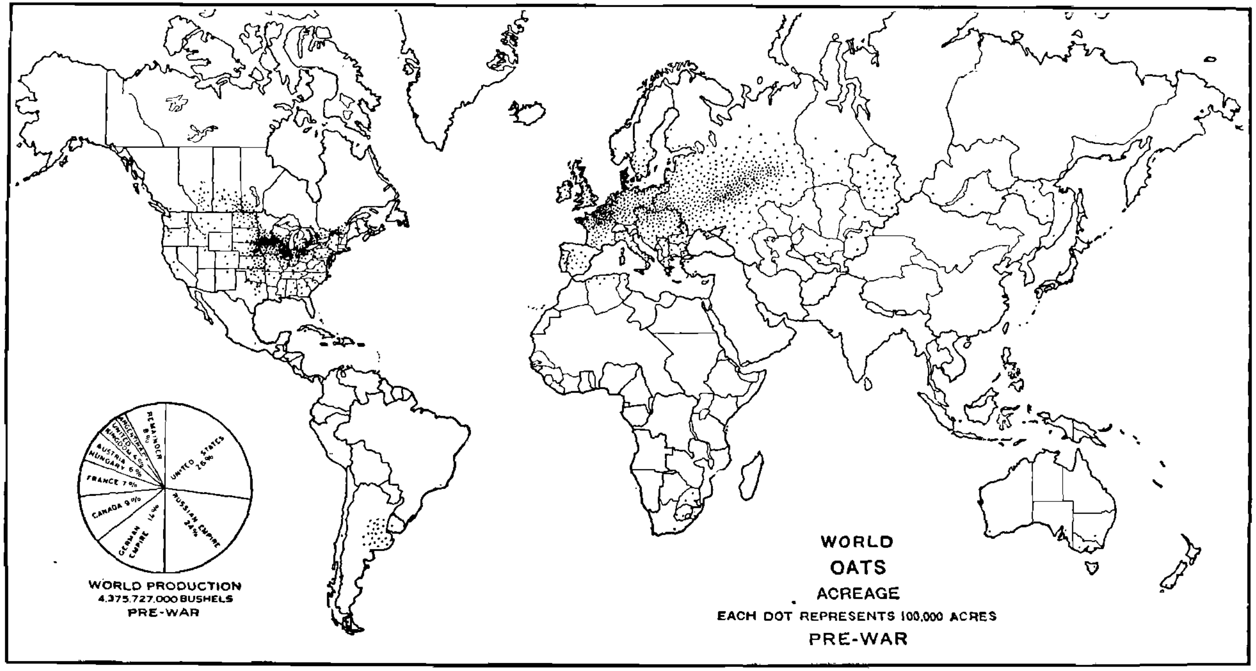

FIG. 67.—Pre-war oat acreage and production of the world. The United Stated led in acreage then, with Russia a close second. Germany, Canada, France and Austria-Hungary followed in the order named. Complete post-war statistics are not available from several important producing countries. Like wheat, most of the world's oats is produced in the North Temperate Zone. (*U. S. Dept. Agr. Yearbook*, 1922).

The biological origin of the oat is not definitely known, but the prevailing opinion holds that two species, *Avena fatua* and *Avena sterilis*, are the progenitors of nearly all of the cultivated oats. The latter species is of more recent origin. The commonly cultivated species of oats, *Avena sativa*, is thought to be descended from *Avena fatua.* However, Trabut (1914) states: "*Avena fatua* gives rise to oats adapted to temperate

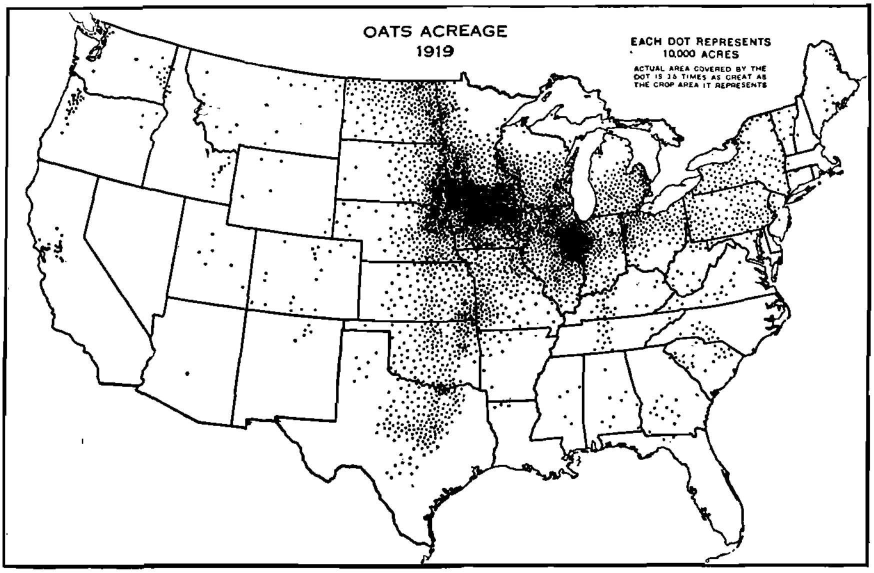

FIG. 68.—The oat belt of the United States consists of a crescent-shaped area extending from New England to North Dakota, bounded on the north by the Great Lakes and on the south by the corn and winter wheat region. An arm extends southwestwardly from this belt across eastern Kansas and Oklahoma to central Texas. Oats prefer a cool, moist climate, and this large acreage in the corn belt and southwesterly is due more to the need of feed for horses, and of a spring grain nurse crop for clover, than to particularly favorable climatic conditions. In the Southern States most of the oats are fall-sown, but in the North the oats are sown in the spring. (*U. S. Dept. Agr. Yearbook*, 1921).

and mountainous regions; *Avena sterilis*, to oats adapted to tne southern countries, and to saline soils; *Avena barbata*, to races adapted to dry countries."

Classification.—The classification of oats as given by Carleton (1916, page 95) is as follows:

Avena	*fatua*	*sativa*, common or spreading oats
		orientalis, side oats
		nuda, hull-less oats
	sterilis	*Algeriensis*, red or Algerian oats
	barbata	*strigosa*, rough or sand oats
		brevis, short oats
	Wiestii	*Abyssinica*, Abyssinian oats

The oats which will be considered in this discussion are those belonging to the first group. Oats are sometimes grouped according to shape of head or panicle, color of seed, time of seeding and days to maturity.

Shape of Head.—In the common or spreading oats, the panicle is usually upright and the branches are about equally distributed on all sides. In the case of the side or "horsemane" oats, the head usually droops and the branches are on one side. However, there are all gradations between these two types.

The common or spreading oats include most of the cultivated varieties. They differ from each other in awn character, form, size and color of kernel, time of maturity and so forth. There are both winter and spring varieties.

The side oats seem to be somewhat more restricted in their adaptation than spreading oats. They possess a compact panicle, and for this reason their probable ability to yield is placed too high. As a rule side oats do not produce as large yields as spreading oats under the same conditions. In case of side oats there are only spring varieties.

Color of Oats.—Oats may be classified as to the color of the hull. The five principal colors are white, black, red, yellow and gray. In the North the oats commonly grown are white, but black and yellow varieties are also grown. In the South the red and gray oats are chiefly grown.

Time of Seeding.—Oats may be classified as spring and winter, according to the time of seeding. Winter oat production is limited to the southeastern portion of the United States and nine-tenths of the oat crop is spring-sown. Often the same variety is sown either in the fall or in the spring, and a variety seeded in the fall in the South may be seeded in the spring farther north. The fall-sown oats ripen a month to 6 weeks earlier than the spring plantings. Thus, many of the winter oats are not true winter types. However, the Winter Turf or Virginia Gray Winter oats are true winter oats.

Days to Maturity.—Oats are sometimes grouped as early and late, according to the days from time of planting to maturity. In the case of fall seeding of such varieties as Fulghum and Virginia Gray Winter, the latter matures about 10 days later. Likewise, in spring seeding, Silvermine matures 2 to 3 weeks later than the Burt variety.

Hull-less Oats.—These oats, which are also called Chinese hull-less, are but little grown in the United States. They do not yield well and are usually grown as a curiosity. In the threshing process, the kernel separates from the hull.

Regions and Varieties.—According to Stanton (1922), the United States may be divided into the four following oat regions (Fig. 69): (1) The Fall Red oat region; (2) the Spring Red oat region; (3) the Early Yellow oat region; and (4) the Mid-season White oat region.

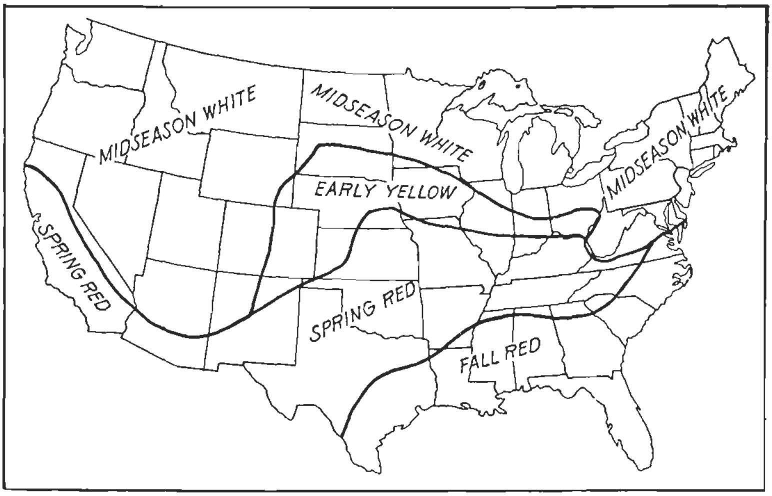

FIG. 69.—Outline map of the United States showing the oat regions. (*U. S. Dept. Agr., Cereal Investigations*).

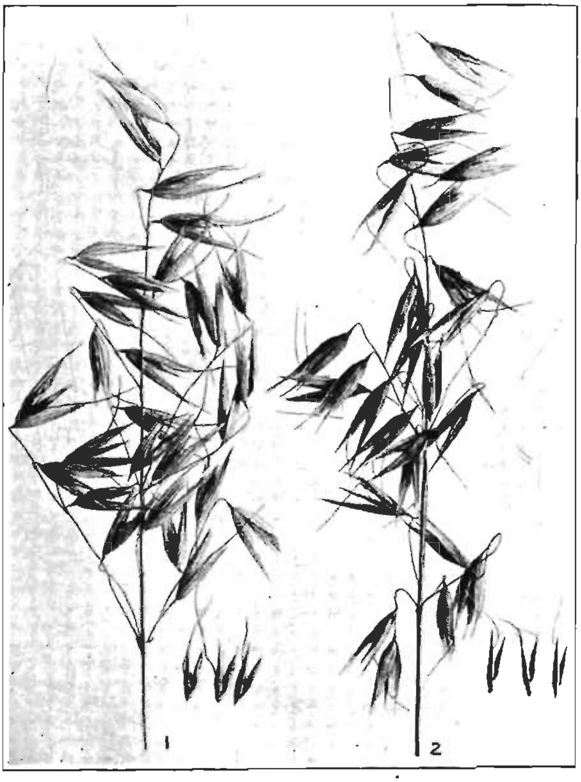

FIG. 70.—Panicles and spikelets of Early Red oats: (1) Red Rustproof, and (2) Burt. (*U. S. Dept. Agr., Cereal Investigations*).

The *Fall Red* oat region corresponds approximately to the cotton belt. The chief varieties are Red Rustproof, Winter Turf, Fulghum, Culberson and Dwarf Culberson.

The principal synonymous varieties of the Red Rustproof are Appler, Bancroft, Cook, Dannier, Ferguson No. 71, Hastings, McGehee, Patterson and Red Texas.

The principal synonymous varieties of Winter Turf are Virginia Gray, Grazing and Oregon Gray.

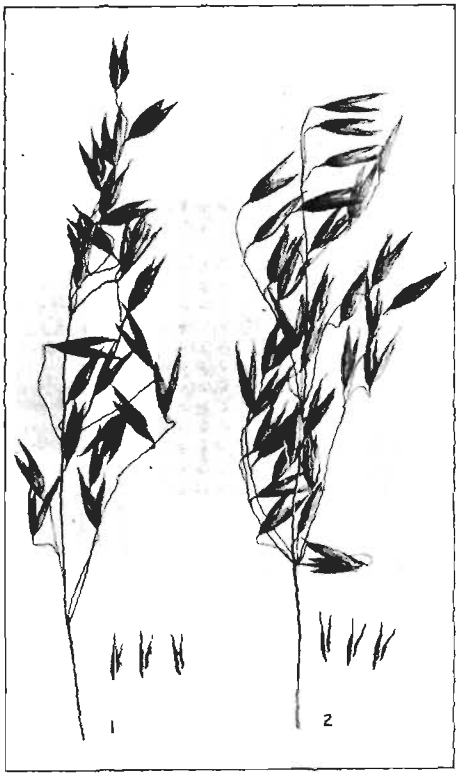

Fig. 71.—Panicles and spikelets of Early Yellow oats: (1) Kherson, and (2) Sixty-day. (U. S. Dept. Agr., Cereal Investigations).

These varieties may be sown either in the fall or the spring. However, the Winter Turf oats are usually not sown in the spring.

The *Spring Red* oat region varieties are the Red Rustproof, Burt, Fulghum, Kanota and Coast Black.

The *Early Yellow* oat region represents in a general way the corn belt. The chief varieties are Albion (Iowa 103), Daubeney, Early Champion, Green Russian, Iowar, Kherson, Richland Iowa (Iowa 105) and Sixty Day. Some of the varieties of side oats are also grown in this region.

The *Mid-season White* oat region includes the northern section of the country and some of the southern portion in the western states. The varieties grown are Abundance, Banner, Big Four, Clydesdale, Cornellian, Danish Island, Green Russian, Golden Rain, Idamine, Irish Victor, Ligowo, Lincoln, O. A. C. No. 72, Probsteier, Silvermine, Swedish Select,

FIG. 72.—Panicles and spikelets of Mid-season White oats: (1) Victory, (2) Silvermine and (3) Swedish Select. (*U. S. Dept. Agr., Cereal Investigations*).

Worthy and Victory. The principal side oats of this district as well as of the Early Yellow oat district are Storm King, Tartar King, White Tartar, Black Tartar and White Russian. The Oregon Gray or Winter Turf is grown to some extent on the Pacific Coast in Oregon and Washington.

Uses.—The oat crop is used chiefly as a grain feed for horses. It is also a good feed for many other classes of live stock, but its comparatively high price limits its use primarily to a feed for horses. Oats are not especially suited for feeding to hogs on account of the high percentage of fiber. When in the milk stage the crop is sometimes cut for hay.

The oat kernel is also used for making oatmeal for human consumption. In the manufacture of oatmeal, the hull is a by-product sometimes mixed with other materials for making feed for live stock.

In 1920, the United States imported 6,728,000 bushels of oats, including oatmeal, and exported 16,540,000 bushels. The production during this same year was 1,496,281,000 bushels.

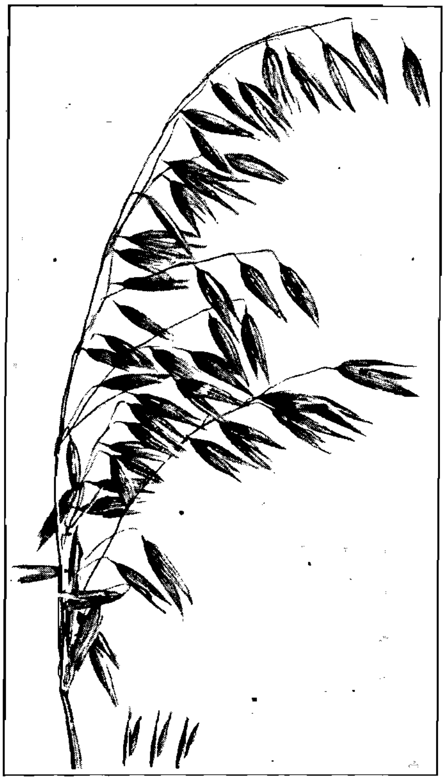

FIG. 73.—Panicle and spikelets of White Russian (side) oats. (*U. S. Dept. Agr., Cereal Investigations*).

CULTURE

Seed.—The grower should attempt to use good seed of the variety best adapted to the region in question. There has been considerable improvement made with the oat crop along breeding lines. The Kanota and Fulghum selections are valuable, and among the hybrids may be mentioned the cross Burt X Sixty Day. The improved strains should receive consideration by the grower.

The selection of seed oats by the use of the fan mill has not proved very profitable; but when the seed is selected by hand so as to secure a

comparatively large difference in size of seed, the yield from heavy seed is usually more than that from light seed. These results do not mean that the fan mill should not be used, since its use is valuable in the removal of inert matter, diseased seeds and certain foreign seeds.

Time of Seeding.—The time of seeding both fall and spring oats in the various states is given in Chapter XIV. In case of both kinds of oats early seedings are important. The need of early seeding of fall-sown oats in order to insure maximum yield is shown by the results of Hutcheson (1908). The tests were conducted in the portion of Virginia on the border between the spring and winter oat regions. The 4-year average results show that Culberson oats seeded on September 15, yielded 30.64 bushels; on September 30, 28.06 bushels; on October 15, 15.32 bushels; and on October 30, 2.54 bushels.

The advantages from early seedings of spring oats is shown by the results secured by Morrow and Gardner (1894) in Illinois. It was found, as a rule, that the yield of both straw and grain, weight per bushel and the percentage of kernel decreased with the lateness of seeding. Georgeson, Burtis and Otis (1897*a*) also recommend early seeding for Kansas.

Rate of Seeding.—The usual rate of seeding oats is from 8 to 10 pecks, except under dry farming and irrigation conditions. Under the latter conditions the rate of seeding is somewhat less, usually 6 to 10 pecks. Also, warm, dry soil and early seedings favor somewhat lighter seedings.

Georgeson and other (1897*a*) in Kansas found as an average for 7 years, that the most profitable rate of seeding was 2 to 2½ bushels of seed per acre. Davenport and Fraser (1896) recommended 2½ bushels as the most favorable rate of seeding in Illinois. Hays (1894) in Minnesota found that 9 pecks of seed produced the largest amount of grain, and 11 pecks of seed per acre the largest amount of straw. In Ohio, Williams (1903) found 9 or 10 pecks of seed per acre more profitable than a smaller quantity. Merrill (1898) in Utah, found that 2 bushels of seed per acre gave better results than a larger or smaller quantity of seed.

Depth of Seeding.—Oats are generally seeded 1 to 2 inches deep. However, on a dry sandy soil they may be seeded deeper than on a moist clay soil.

Williams (1903) in Ohio seeded oats 1, 2, 3 and 4 inches deep. The 1-inch depth proved best as shown by the results in Table XCVIII.

Davenport and Fraser (1896) in Illinois found as an average of six seasons, that oats planted 1 inch deep yielded more than those planted deeper. Hays (1894) reports 1½ to 2½ inches the most favorable depth for planting oats in Minnesota.

Methods of Seeding.—In the sowing of oats the seeds should have a uniform covering of the proper depth. This practice will insure good germination, other things being equal. Oats are sown both broadcast

and drilled, but it seems that drilling is much the more desirable method of seeding.

TABLE XCVIII.—DEPTH OF SEEDING OATS IN OHIO (AVERAGE 1897 AND 1898)

Depth in in.	Yield per acre		Straw per bu. of grain, lb.	Weight per measured bu., lb.
	Grain, bu.	Straw, lb.		
1	56.01	2,655	47.40	28.56
2	52.45	2,192	41.80	29.55
3	48.28	1,955	40.49	29.00
4	48.28	1,775	36.76	29.00

Georgeson and others (1897*a*) found the 7-year average yield of oats in Kansas from broadcast seeding to be 26.24 bushels; from seeding with hoe drill, 28.34 bushels; with shoe drill with press wheels, 31.54 bushels; and with the latter drill without press wheels, 30.01 bushels. Hume and others (1909) in Illinois found that the 2-year average yield of oats from drilled plats was 33.3 bushels per acre, and from broadcasted plats, 29.7 bushels. At the Ohio Station, Williams (1903) obtained practically the same yields from broadcasting as from drilling. It was thought, however, that the oats were drilled too deep for best germination. At Lincoln, Nebraska, Kiesselbach and Ratcliff (1917) obtained results which agreed with those obtained by Williams. However, at the North Platte, Nebraska, Experiment Station the increase in yield in favor of drilling was 8.7 bushels per acre.

Cultivation.—It is doubtful whether the cultivation of oats will pay except in dry years; and even then the crop will succeed best when drilled. The practice is not generally followed.

Montgomery (1910) found that the cultivation of drilled oats increased the yield 5.3 bushels per acre, while the cultivation of broadcasted oats decreased the yield 1.9 bushels under Nebraska conditions.

SOME DISEASES

Among other diseases, the oat crop is affected by loose smut (*Ustilago avenae*) and covered smut (*Ustilago laevis*). These two smuts may be considered as one from the economic standpoint, since they are similar in appearance and since both are controlled by the same treatment.

The loose smut of oats is very similar to loose smut of wheat in appearance. All parts of the flowers are affected and turn into black, sooty masses of spores. The covered smut of oats differs from the loose smut of oats in the less complete destruction of the flower parts and in less

profuse production of spore masses, which are somewhat blacker than those of loose smut.

Infection of the two smuts takes place in a manner similar to that of bunt of wheat, both in the field and in threshing. The spores are retained on the surface of the grain. If not destroyed, they germinate in the soil with the seeds and thus infect the young plants. These in turn produce smutted heads.

The formaldehyde treatment as given for bunt or stinking smut of wheat is usually recommended.

CHAPTER XXXII

BARLEY (Hordeum spp.)

The area suitable for the profitable production of barley in the United States is less extensive than that for corn, wheat or oats. However, the crop deserves more attention than it has received. In 1919 barley ranked seventh in acreage and eighth in value as compared with the other crops.

World Production.—Figure 74 shows the world production and acreage of barley for the 10-year period, 1906 to 1915.

Average Acre Yield.—The average yield of barley per acre for the 10-year period, 1910 to 1919, was, for the United States, 25.1 bushels; Russia, 15.6 bushels; Germany, 33.2 bushels; Austria, 26.3 bushels; Hungary, 24.2 bushels; France, 23.1 bushels; and the United Kingdom, 33.6 bushels.

Production in the United States.—Figure 75 shows the acreage of barley in the United States for 1919.

The average annual yield of barley for the United States as a whole for the 5-year period, 1910 to 1914, was 186,208,000 bushels, with an average acre yield of 24.5 bushels; during the period 1915 to 1919 the average annual production was 205,350,000 bushels and the average acre yield was 25.5 bushels.

The six states, California, South Dakota, Minnesota, North Dakota, Kansas and Wisconsin in 1920 produced 131,750,000 bushels of barley, or 69.6 per cent of the entire crop.

Historical.—Barley has been known for thousands of years and it was cultivated before any recorded history of man. During its early cultivation it was used for making bread, beer, and feed for beasts; and was used by the people of Europe as the chief bread material until as late as the sixteenth century. Barley is supposed to have originated in western Asia.

Barley was grown by the early colonists in the United States. In the early part of the seventeenth century it was grown in Massachusetts and Virginia, and later in the same century it was grown in Rhode Island and New York. In 1839 there were 4,161,504 bushels of barley grown; in 1909 the production was 173,344,212 bushels, while in 1920 the production was 189,332,000 bushels.

The biological origin of barley is not definitely known. The six-row barley is probably the form first cultivated. The oldest form now known

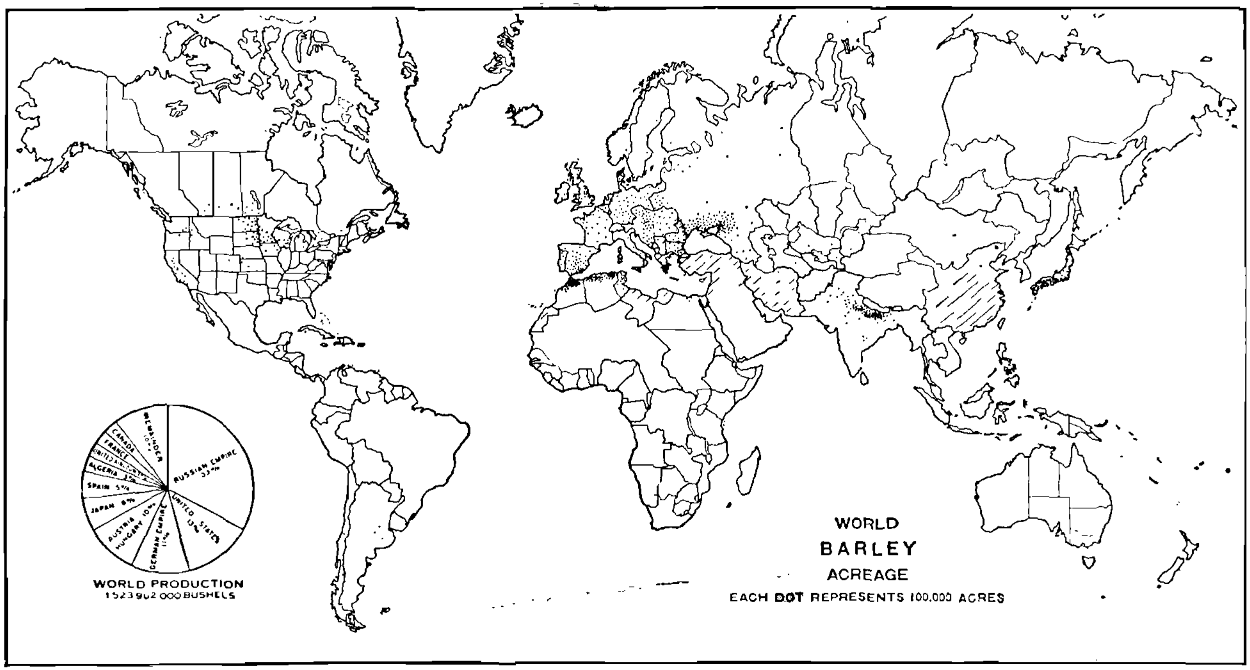

FIG. 74.—World pre-war acreage and world production of barley. No statistics were available for China, Persia, Asia Minor and part of northern Africa. The four great centers of production are seen to be in southern and western Europe and northern Africa, the United States, British India and Japan. Complete statistics are not available for many of the large producing countries, notably Russia, since the war. (*U. S. Dept. Agr. Yearbook*, 1922).

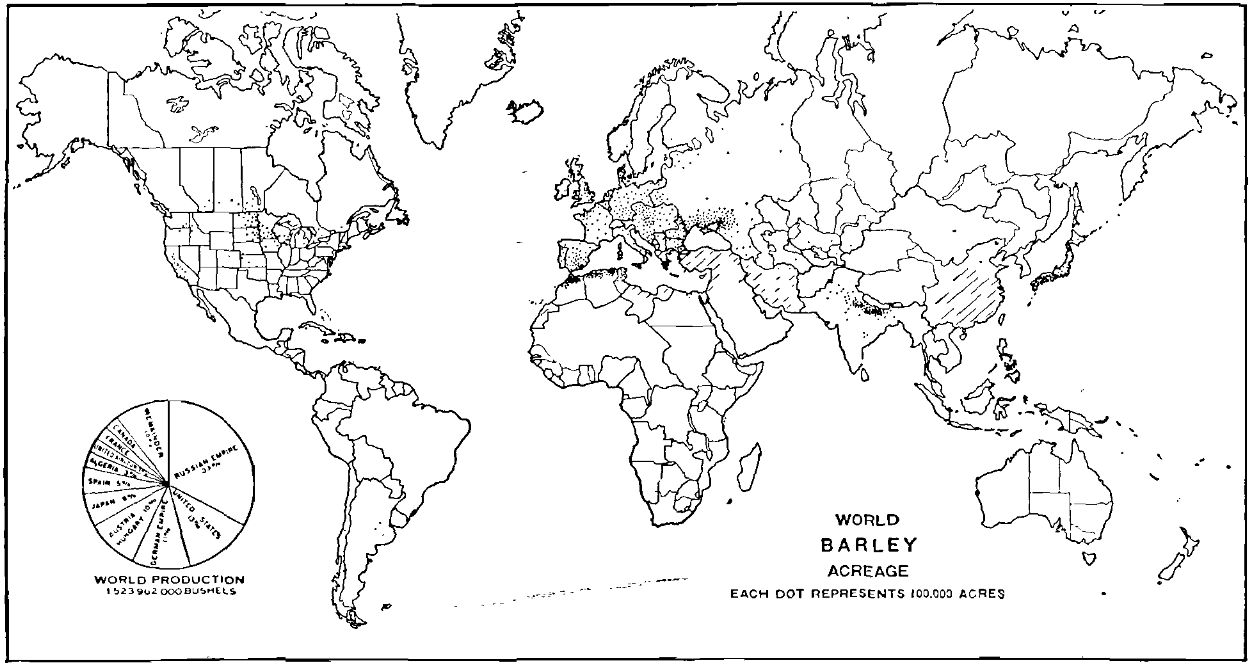

Fig. 74.—World pre-war acreage and world production of barley. No statistics were available for China, Persia, Asia Minor and part of northern Africa. The four great centers of production are seen to be in southern and western Europe and northern Africa, the *United* States, *British India* and *Japan*. Complete statistics are not available for many of the large producing countries, notably Russia, since the war. (*U. S. Dept. Agr. Yearbook*, 1922).

to be growing wild is *Hordeum spontaneum*, a species very similar to the present two-row barley. Wiggans (1921) states that this species may be the ancestor of some or all of the cultivated barleys.

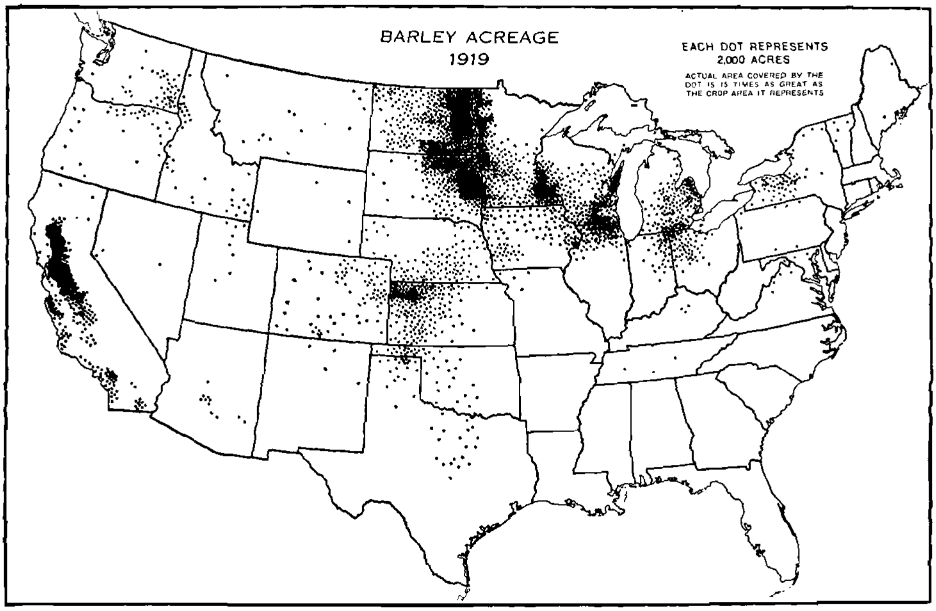

FIG. 75.—It should be noted that a dot on this map represents only one-fifth as much acreage as on the maps of corn, wheat and oats. Barley is a minor crop in the United States compared with these crops, except in southeastern Wisconsin, southeastern and northwestern Minnesota, and eastern portions of the Dakotas and the valleys of California. In these five states nearly two-thirds of the nation's barley acreage is found. Minor centers may be noted on the map in northwestern Kansas, southeastern Michigan and northwestern New York. These barley districts are characterized by a cool, sunny climate. The crop in California is grown during the winter. Much barley is also sown in California to be cut green for hay. (*U. S. Dept. Agr. Yearbook*, 1921).

Classification.—The classification as given by Wiggans (1921) is as follows:

Hordeum
- *spontaneum*—two-row wild barley
- *vulgare*—six-row barley
- *intermedium*—six-row barley
- *distichon*—two-row barley
- *deficiens*—two-row barley

The classification as given is based on the number of rows of grain and their arrangement. A diagrammatic view of the cross-section is given in Fig. 77 as given by Wiggans (1921).

Hordeum spontaneum is of interest because of the probability of its being the ancestor of cultivated barleys. It is a two-row type.

Hordeum vulgare, a six-row barley, is widely grown in the United States and is the most important species. In this species all three spike-

lets at each node of the spike are fertile. There are dense and lax forms, according to the arrangement of the spikelets, as shown in Fig. 78.

Hordeum intermedium, a six-row type, is probably of hybrid origin, as illustrated by the Arlington Awnless, and is grown rather extensively in the United States. As shown in Fig. 79, all three spikelets develop; but the grain of the lateral spikelets are smaller than that of the median.

FIG. 76.—Four cultivated species of barley. Left to right; *Hordeum deficiens*, *H. distichon*, *H. intermedium*, *H. vulgare*. (*N. Y. (Cornell) Agr. Expt. Sta. Mem.* 46).

Hordeum distichon, a two-row type of barley, is grown rather widely in the United States. As illustrated in Fig. 80, only the median spikelets are fertile. Although the lateral spikelets are infertile, they possess all the floral organs.

Hordeum deficiens, a two-row barley, is distinguished from *Hordeum distichon* by the reduction in floral parts of the lateral spikelets. Only the median spikelets produce grain. This species is not of economic importance in the United States at the present time.

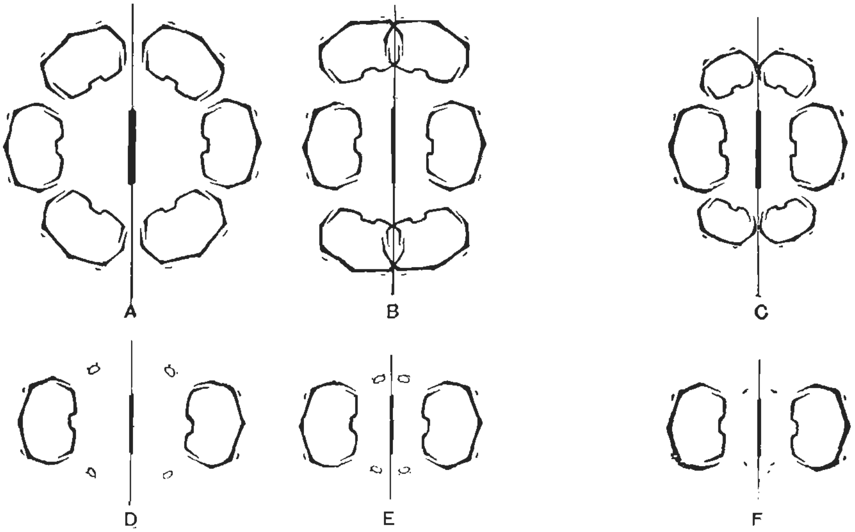

FIG. 77.—Diagrammatic sketch of cross-sections of spikes of various types of barley: *A*, *H. vulgare* (dense form); *B*, *H. vulgare* (lax form); *C*, *H. intermedium*; *D*, *H. distichon* (dense form); *E*, *H. distichon* (lax form); *F*, *H. deficiens*. (*N. Y.* (*Cornell*) *Agr. Expt. Sta. Mem.* 46).

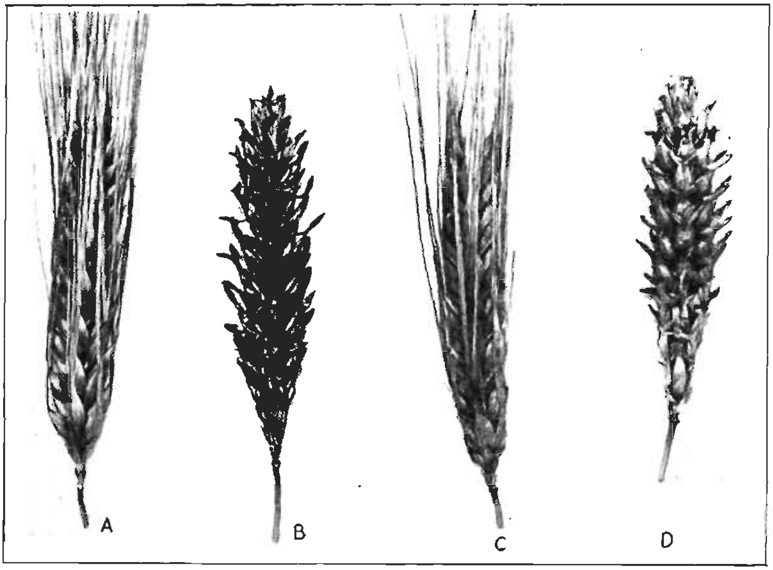

FIG. 78.—Varieties of *Hordeum vulgare*: *A*, lax, hulled, awned; *B*, lax, hulled, hooded; *C*, lax, hull-less, awned; *D*, lax, hull-less, hooded. (*N. Y.* (*Cornell*) *Agr. Exp. Sta. Mem.* 46).

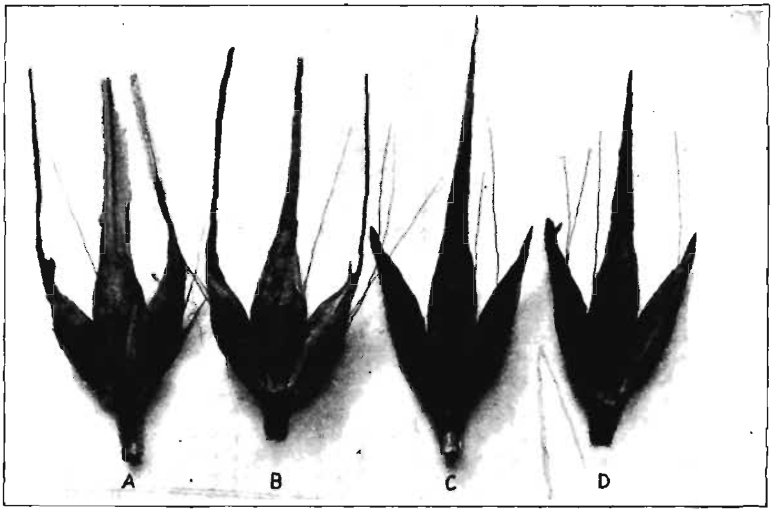

Fig. 79—The structure of six-row barleys: *A*, dorsal view of perfect condition of fertility, where all spikelets are equally fertile and awned; *B*, ventral view of same; *C*, dorsal view of second condition of fertility, where side spikelets are fertile but about one-half the size of median spikelets and not awned; *D*, central view of same. (*N. Y. (Cornell) Agr. Exp. Sta. Mem.* 46).

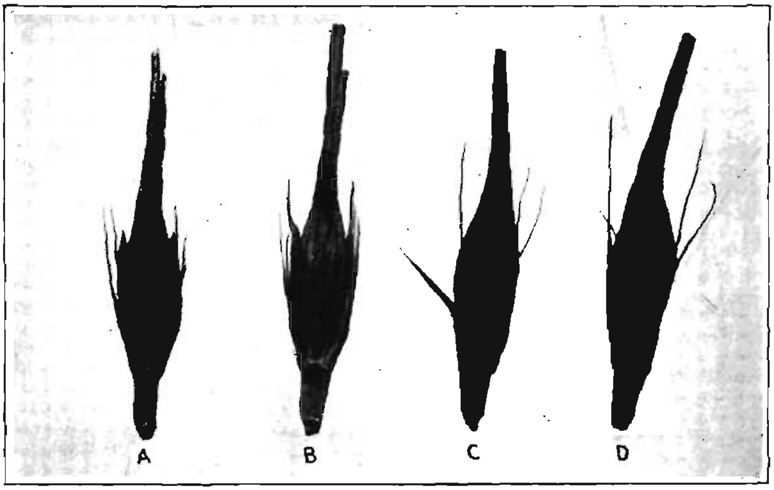

Fig. 80.—The structure of two-row barleys: *A*, dorsal view of third condition of fertility, where side spikelets are infertile but possess all structural parts except terminal appendage of lemma; *B*, ventral view of same; *C*, dorsal view of fourth condition of fertility, where side spikelets are very rudimentary; *D*, ventral view of same. (*N. Y. (Cornell) Agr. Exp. Sta. Mem.* 46).

Types of Awns.—Wiggans (1921) has divided barleys into three types in regard to the awn characters: (1) awned or bearded barleys; (2) awnless or beardless barleys; and (3) hooded barleys.

The awn may be barbed or smooth, as shown in Fig. 81. Most varieties of barleys hold their awns but some lose them when the grain ripens. The awnless or beardless barley should not be confused with the hooded barleys. In the case of hooded barleys, the normal awn is replaced by a trifurcate structure called the hood.

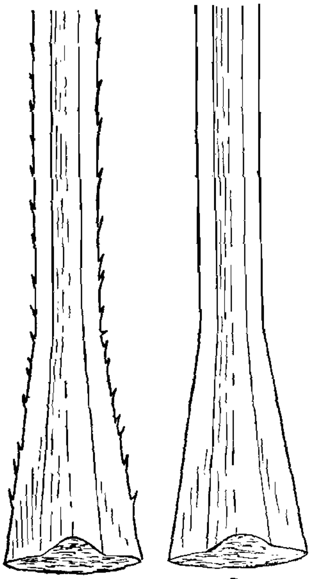

Fig. 81.—Variation in barbing of awns: *A*, barbed; *B*, smooth. (*N. Y. (Cornell) Agr. Expt. Sta. Mem.* 46).

Color of Grain.—Harlan (1914) states that there are four colors in barley: white or yellow, blue, purple and black. Owing to immaturity or to some condition such as weathering, brown and greenish colors may appear. It was found that the pigmentation was the result of two pigments, anthocyanin and a melanin-like pigment.

Winter and Spring Barleys.—There are both winter and spring types of barley. The latter type is grown more extensively in the United States. Winter barley is less cold-resistant than winter wheat or winter rye, and its production is limited to the southeastern section of the country.

Hull-less Barleys.—Generally, the barley kernel is surrounded by a hull; and in such a case the kernel and hull together constitute the grain. However, in each of the main groups, both hull-less and hulled varieties are found.

Regions and Varieties.—Harlan (1918) has divided the country into three districts as far as barley production is concerned. These districts are: (1) the humid spring region; (2) the semi-arid region; and (3) the humid winter region. They are shown in Fig. 82.

The *humid spring region* is the most important. In this region the six-row barleys are chiefly grown. The Manchuria and Oderbrucker are the most important varieties of this section.

In the *semi-arid spring region* both the two-row and six-row barleys are grown. In the northern portion the two-row barleys are grown almost exclusively, while in the southern and intermountain regions both two-row and six-row types are grown. The most widely grown barley in this region is the Coast variety, which is six-rowed, awned and hulled. The two-row varieties widely grown are Chevalier, White Smyrna and Hannchen. The Chevalier seems to do well under irrigated as well as

under non-irrigated conditions. In the mountains, the Nepal, a six-row, hooded variety, is often grown. In the Southern Plains, Horsford, a six-row, hulled variety, is sometimes used. Gatami, a six-row barley, does well where the season is likely to become dry early and suddenly. The Mariout, a six-row, bearded, hulled variety, does well in California. In the Great Basin, some winter barley is grown. The variety frequently used is Utah Winter, a six-row, bearded, hulled variety.

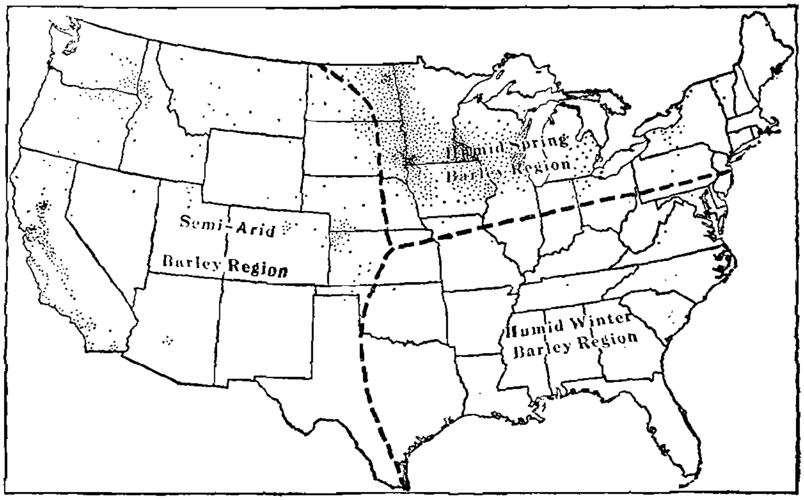

FIG. 82.—Outline map of the United States, showing the three general regions of barley production. The dots indicate the acreage of barley, according to the Census of 1909. Each dot represents 5,000 acres. (*U. S. Dept. Agr. Farmer's Bul.* 968).

In the *humid winter region* the Tennessee Winter, a six-row, bearded, hulled variety is the principal variety grown. In this region Union Winter variety, very similar to the Tennessee Winter, is widely used; and it has been stated that these two varieties are practically identical. However, Mooers, of the Tennessee Experiment Station, states that they are different.

The varieties of barley most commonly cultivated, with description and adaptation are given in Table XCIX, taken from Harlan (1918).

Quality of the Barley Grain.—Le Clerc and Wahl (1909), from a discussion of the quality of the barley grain from the standpoint of malt production, have reached the following conclusions:

The endosperm varies in texture from "mealy" to "hard or vitreous." The "mealy" barley grains, which are low in protein, contain about 10 per cent; the "hard or vitreous" grains, which are relatively high in protein, contain about 12 to 14 per cent. The six-row barleys are usually higher in protein than the two-row types. A low protein barley is desirable for malting purposes.

Table XCIX.—Description and Adaptation of the Varieties of Barley Most Frequently Found in Field Culture

Classification, variety and synonyms[1]	Description					Region adapted	Area of special adaptation
	Kernel rows	Color[2]	Hull	Awns	Spike		
Three principal type varieties:							
Coast	6	White	Hulled	Awned	Lax	Arid	
Manchuria and Oderbrucker (*Manshury*).	6	White	Hulled	Awned	Lax	Humid spring	
Tennessee Winter	6	White	Hulled	Awned	Lax	Humid winter	
Important minor varieties of less extensive distribution:							
Chevalier	2	White	Hulled	Awned	Lax	Arid, irrigated	Northern irrigated lands
Hannchen	2	White	Hulled	Awned	Lax	Arid	Northern Plains and the West
Mariout	6	White	Hulled	Awned	Dense	Arid	Late seeding in California and in the Great Basin
Smyrna, white	2	White	Hulled	Awned	Lax	Arid	Montana
Trebi	6	White	Hulled	Awned	Lax	Arid, irrigated	Great Basin
Winter Club (*White Club, Utah Winter*).	6	White	Hulled	Awned	Dense	Arid	Great Basin, fall seeding
Less important minor varieties:							
Beldi	6	White	Hulled	Awned	Lax	Arid	About as Coast
Gatami	6	Black	Hulled	Awned	Lax	Arid	Severe summer conditions, Northern Plains
Hanna	2	White	Hulled	Awned	Lax	Arid, humid spring	
Himalaya (*Guy Mayle*).	6	Blue	Naked	Awned	Lax	Arid	Northern Plains
Horsford (*Success, Beardless*).	6	White	Hulled	Hooded	Lax	Arid	Southern Plains
Nepal (*White Hull-less, Beardless*).	6	White	Naked	Hooded	Lax	Arid, humid spring	Rocky Mountains

[1] Synonyms are indicated by italic type in parentheses.

[2] In the hulled varieties the color refers to the glume only. Some of the white-hulled sorts have blue aleurone layers.

If the grain is intended for malting purposes, it should germinate uniformly, quickly and completely; be free from discoloration; and preferably be of a bright straw color, having a good percentage of hull.

In this country barley is now chiefly used as a feed crop. For this purpose the question of germination is not so important so long as the grain is of good quality.

Uses.—Barley is used for malting, pearling, breakfast food preparations and flour. Barley is coming into greater prominence as a stock

feed since its use for malting purposes has decreased. It has proved to be a good grain feed and is used in many instances to take the place of corn. Although barley is somewhat higher in protein than corn, it is also carbonaceous. It is, therefore, a good plan to feed it in connection with feeds high in protein.

Culture

Seed.—It is important to choose the varieties best suited to the region in question. A superior grade of seed, of the variety chosen, is of great value in securing large yields. The farmer should clean the seeds with a fan mill or seed cleaner before planting. This operation will remove much of the inert matter, weed seeds and light-weight and diseased seeds. Soule and Vanatter (1901) under Tennessee conditions obtained an increase in yield of 10.6 bushels from large seeds as compared with small seeds.

Time of Seeding.—The time of seeding both fall and spring barleys in the various states is given in Chapter XIV.

In case of winter barley, Mooers (1915) in Tennessee, found as an average for 6 years that barley seeded September 17 to 29 yielded 50.9 bushels per acre; October 3 to 7, 47.9 bushels; and October 14 to 19, 38.2 bushels. Hutcheson (1908) also found under Virginia conditions that barley seeded the last two weeks in September yielded better than that planted later. In general, barley should be seeded after winter oats. This date also seems best for Kansas, according to Ten Eyck and Shoesmith (1907).

Harlan (1918) states that spring barley should be seeded at the same time that spring wheat is sown, if maximum yields are to be expected. In the Northern Plains the most favorable time of seeding is from April 15 to 25. A loss of at least 1 per cent per day is to be expected for each day the seeding is delayed after April 25. Ten Eyck and Shoesmith (1907) in Kansas report that spring barley can be seeded over a relatively long period of time. In one test the highest yield was obtained from March 30 seeding; in another test, from seeding made on February 1. Hays (1894) in Minnesota found that barley seeded on April 27 and on May 27 yielded practically the same.

Rate of Seeding.—Harlan (1918) states that in humid sections 2 bushels of barley are usually seeded per acre. In the Northern Plains 4- and 8-peck seedings have given about equal returns. The usual recommendation is 4 to 6 pecks. In dry years 4 pecks are sufficient. In the driest portion of the Dakotas, in Montana and in the Great Basin, 3 pecks frequently give good results. In California 7 pecks are generally used. In case hull-less varieties are used, the rate of seeding is about three-fourths that of hulled seed.

Huntley (1894) recommends 8 pecks of barley as the proper rate of seeding for Colorado. Hays (1893*a*) recommends 8 to 10 pecks of seed for North Dakota.

Depth of Seeding.—Harlan (1918) states that in humid regions barley should be seeded about 1½ inches deep. In the Northern Plains the depth should be about 2 inches; in the Great Basin, 2½ to 3 inches.

Hays (1894) in Minnesota found that barley seeded 3½ inches deep gave a larger yield of grain than shallower seeding, but a smaller yield of straw. However, Boss (1893) at the Minnesota Experiment Station found that a 2-inch depth of seeding was most favorable to the yield of both grain and straw.

Method of Seeding.—As with wheat and oats, drilling barley gives better results than broadcasting the seed. Derr (1911), quoting from the Nebraska and Wyoming Experiment Stations, advises that barley should be drilled instead of broadcasted.

SOME DISEASES

There are two smuts of barley which correspond to the loose smut and bunt of wheat. The smuts which affect barley are called loose smut and covered smut; and they are caused by the fungi *Ustilago nuda* and *Ustilago hordei*, respectively. These two fungi attack only the barley plant.

Loose Smut.—The loose smut of barley is very much like the loose smut of wheat in appearance, the entire head being destroyed. The life history is identical with that of the loose smut of wheat fungus, the infection taking place only when the barley heads are in flower.

The hot water treatment is necessary for control and the same method is used as for wheat except that a lower temperature is advisable. The temperature of the water should be 126° F. (admissible range 124 to 129° F.) and the time of exposure should be 13 minutes. The period of presoaking in cold water should be as for wheat, about 4 hours.

Covered Smut.—The covered smut of barley is somewhat like bunt of wheat in appearance. However, the diseased heads have no odor and they are more completely destroyed than bunted heads of wheat. The diseased heads have a dark, gray color when mature, usually appear later, and are borne on shorter stalks than normal heads. Often they scarcely emerge from the boot. In the threshing process, the smut balls are broken and the spores contaminate the healthy seeds. The life history of the covered smut of barley is similar to that of bunt of wheat and the formaldehyde treatment described for this disease will control the covered smut of barley.

CHAPTER XXXIII

RYE (Secale cereale)

Rye is hardier than wheat and will grow on some lands not suitable for wheat. It is well adapted to the same regions as wheat and also may be grown farther north. In 1909 the value of the rye crop of the United States was less than one-half of 1 per cent of the value of all crops. In 1919 rye ranked ninth in value and sixth in acreage, being on a par with sweet potatoes in value.

World Production.—The average total yield of rye for the world in 1909 to 1913 was 1,755,598,000 bushels. Of this crop, 96.4 per cent was produced in Europe. Of the 1909 crop, 45 per cent is to be credited to Russia; 25 per cent to Germany; 6 per cent to Austria; 5 per cent to Poland; 2 per cent to the United States; and 17 per cent to the remainder of the world.

In 1920 the United States produced 60,490,000 bushels of rye, or 10.1 per cent of the world production.

Average Acre Yields.—For the 10-year period, 1910 to 1919, the average acre yield of rye was as follows: the United States, 12.7 bushels; Russia, 11.8 bushels; Germany, 25.2 bushels; Austria, 18 bushels; Hungary, 18.4 bushels; and France, 15.6 bushels.

Production in the United States.—Figure 83 shows the acreage of rye in the United States for 1919.

The average annual yield in the United States as a whole for the 5-year period, 1910 to 1914, was 37,568,000 bushels with an average acre yield of 16.3 bushels; during the period, 1915 to 1919, the average annual production was 66,474,000 bushels and the average acre yield was 14.7 bushels.

The four states, Michigan, North Dakota, Minnesota and Wisconsin in 1920 produced 34,555,000 bushels of rye, or 57.1 per cent of the entire crop.

Historical.—Rye has not been under cultivation so long as wheat or barley. It was unknown to the ancient Egyptians, Greeks, the lake dwellers of Switzerland and its introduction into the Roman Empire was scarcely before the Christian Era. It seems to have been cultivated first in western Asia and southern Russia. It may also be noted that five or six species of the genus *Secale* are to be found in these sections of the world.

Rye was not grown in the United States by the early colonists. In 1839 the production was 18,645,576 bushels; in 1909 the production was 29,520,457 bushels; and in 1920 the production was 60,490,000 bushels. The original species of rye is supposed to be *Secale montanum*, a perennial grass.

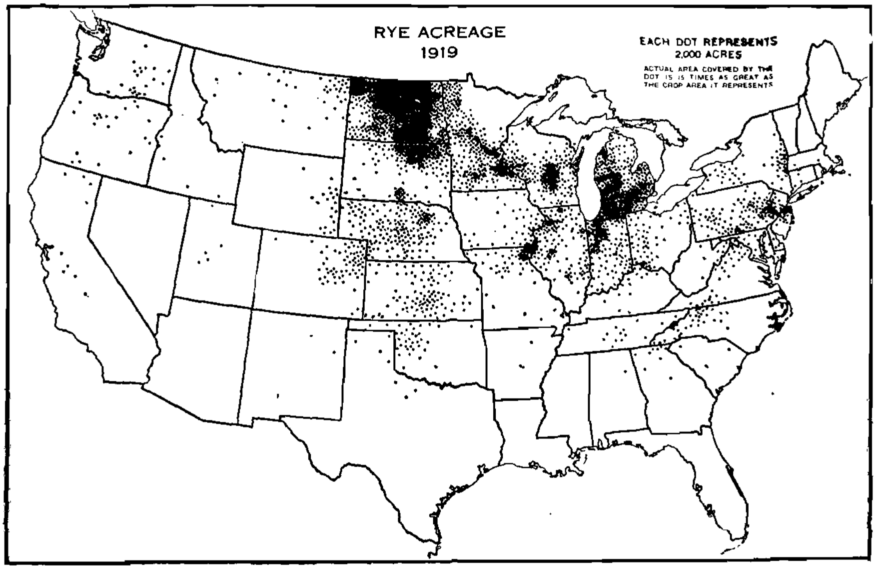

FIG. 83.—Rye acreage in North Dakota increased from 48,000 in 1909 to 2,422,000 in 1919. This acreage in North Dakota in 1919 was almost one-third of the total in the United States, although, owing to an unfavorable season, the production was little greater than in Michigan. Rye heretofore has been grown mostly in the sandy sections of the Lake states, and this sudden extension of production into the subhumid lands of the spring wheat and Great Plains regions is an interesting and probably significant development. The acreage of rye in the United States in 1919 was much greater than ever before, exceeding even the acreage of barley, but has declined nearly half during the past two years. (*U. S. Dept. Agr. Yearbook*, 1921).

Classification.—The classification as given by Carleton (1916, page 152), is as follows:

Secale
- *fragile*
- *montanum*
  - *dalmaticum*
  - *anatolicum*
  - *cereale*

Secale cereale is the only species of importance under cultivation. The grains of rye may be yellow, gray, green or grayish-brown. There are both winter and spring ryes, but approximately 99 per cent of the crop is fall sown.

Varieties.—The varieties of rye of the cotton belt are Abruzzi and South Georgia. In the northern states the varieties found are Minnesota No. 2, Dean, Petkus, Schlanstedt, St. John's and Rosen. In the

northeastern states are found the Mammoth White and Thousandfold varieties. North Carolina Winter and Virginia Winter are grown in the northern cotton belt. Other varieties are Rimpau, Mexican, Arlington Winter and Giant Winter.

In the more northern sections of the country, rye is grown for grain. In the cotton belt, rye has a wide use as a green manure and pasture

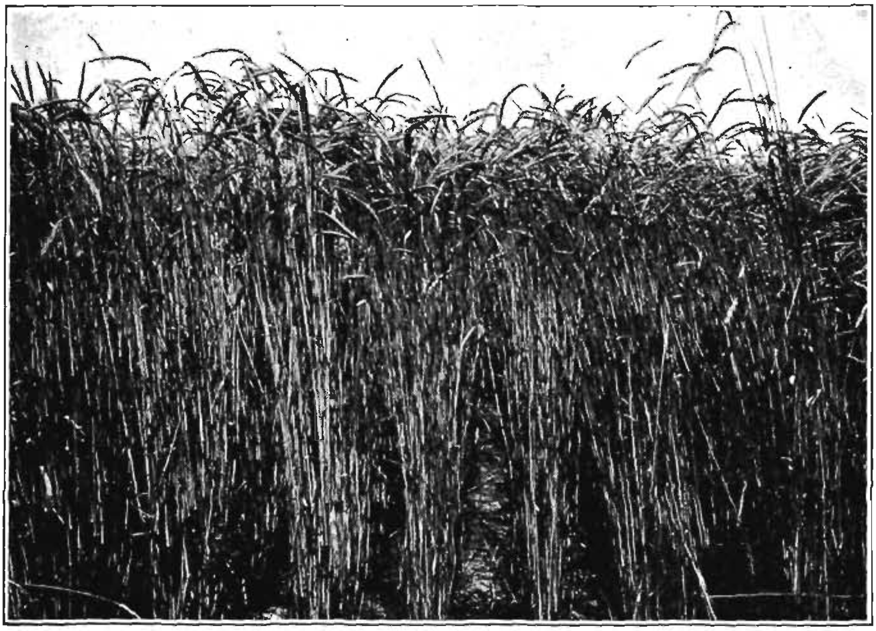

FIG. 84.—A field of Abruzzi rye. This variety is very popular in the South.

crop. Probably the best variety for grazing purposes, where the winters are not too severe, is the Abruzzi.

Uses.—About two-thirds of the rye produced in the United States is used as feed for domestic animals; the remainder is used for making flour and alcohol. The straw is important in the manufacture of paper and packing, and in providing bedding for animals. In some sections the crop is raised more for the straw than for the grain. Rye finds a wide use, especially in the southern states, as cover, green manure and grazing crops.

CULTURE

Seed.—Usually too little attention is given to the selection of well-adapted varieties and good seed in the production of the rye crop. There is a great difference in yielding ability and habit of growth among the

varieties. A variety adapted to the conditions and the purpose for which it is to be used should be chosen.

It is well to fan or clean the seed to remove the small, immature and diseased grains and the seeds of noxious weeds. However, Kiesselbach and Helm (1917) of Nebraska show that large seeds of rye, as separated by the fan mill, yield no more than the small seeds so separated.

Time of Seeding.—The time of seeding winter rye for grain is given in Chapter XIV. Spring rye should be sown at the time spring wheat is seeded; that is, as soon as the ground can be worked. The time of seeding rye will depend on the use to be made of the crop. If the crop is to be used for pasture, for green manure or as a cover crop, it should be sown from 2 weeks to a month earlier than if it is to be used for grain. According to Leighty (1916), in the far northern part of the country, it should be sown for grain about September 1, and in the far South during the latter part of November or later. For purposes other than grain, the crop is seeded about August 20 in the northern states; from September 15 to October 15 in the northern portion of the Gulf states; and about 2 weeks later in the southern portion.

Hutcheson (1908) found in Virginia that rye gave the highest yield of grain, when seeded at the time most favorable for wheat production. However, the date of seeding was not so important with rye as with wheat. Rye seeded on September 15 yielded 15.5 bushels per acre; on September 30, 18.4 bushels; on October 15, 18.5 bushels; and on October 30, 16.9 bushels. Mooers (1915) found under Tennessee conditions that rye for grain should be sown about the same time that wheat is sown. If the crop is to be used as pasture, the seeding should be done 2 to 3 weeks earlier. Boss (1910) states that rye intended for pasture in Minnesota should be sown from August 20 to September 10. When grain production is the prime consideration, the crop should be sown from September 1 to 15.

Rate of Seeding.—If the crop is to be used for pasture or green manuring purposes, the rate of seeding is somewhat heavier than if it is to be used for grain. The usual rate of seeding for grain production is 6 pecks per acre. In the cotton belt the rate of seeding is often less. Hume, Chaplin and Morrison (1915) found in South Dakota as an average of 2 years' results that 5 pecks of rye per acre gave the highest yield. Moore and Leith (1921) recommended seeding at the rate of 6 pecks per acre in Wisconsin. In Virginia the crop is usually sown at the rate of 4 pecks per acre. The usual rate of seeding, when the crop is to be used for pasture, green manuring or soiling, is 2 bushels per acre.

Depth and Method of Seeding.—The usual depth of seeding is from ½ to 2 inches. The depth will vary with the type of soil and season. On sandy soils and in dry seasons the seed should be placed deeper than when the conditions are the reverse.

Better results are usually secured from seeding with the grain drill than from broadcasting the seed. The former method is almost universally practiced.

SOME DISEASES

The rye plant is subject to attack of black stem rust (*Puccinia graminis secalis*), brown leaf rust (*Puccinia dispersa*), stem smut (*Urocystis occulta*), anthracnose (*Colletotrichum cereale*), ergot (*Claviceps purpurea*) and other diseases. The diseases which usually cause the greatest losses are anthracnose and ergot.

Anthracnose.—Anthracnose manifests itself by the premature dying of the portion of the head above the point of attack. In the dead portions there is almost a total loss of grain. The roots and lower portions of the stems are also attacked; and this attack results in a blackened appearance of the affected parts, in a loss in vigor of the diseased plants, which have a tendency to break over, and in the production of shriveled grain. No control remedy is known, but there seems to be some difference in varietal susceptibility. Abruzzi, Florida and Tuscaloosa are said to be somewhat less susceptible than other varieties.

Ergot.—Ergot, according to Leighty (1916), is the most serious and destructive disease affecting rye. The disease is caused by an attack on the ovary by the fungus while the plant is in bloom. The ovary is consumed and replaced by ergot, which is a horny black or purplish body several times larger than the seed of the affected plant. The ergot sclerotia germinate and the spores infect susceptible plants in blossom. When planted these infected seeds reproduce the disease. Ergot also occurs in timothy, Kentucky bluegrass and many other grasses.

Control.—In the control of the disease, ergot-free seeds are necessary. Rye should not follow rye in the rotation if ergot is present, and ergot may be removed from rye by passing the grain through a 20 per cent solution of common salt. The rye grains will sink while the ergots will float. The treatment does not injure germination and the seeds may be sown as soon as the water has been drained away.

CHAPTER XXXIV

BUCKWHEAT (Fagopyrum spp.)

Buckwheat is a comparatively unimportant crop in the United States. According to Leighty (1919), for every bushel of buckwheat there are produced 200 bushels of corn, 50 bushels of wheat, 80 bushels of oats, 12 bushels of barley and 4 bushels of rye.

World Production.—Leighty (1919) states that, from a computation based on the 1909 to 1913 average, the United States ranked third in buckwheat production with its 16,616,000 bushels, while Russia was first with 55,000,000 bushels and France second with 21,000,000 bushels.

Production in the United States.—In the United States buckwheat, unlike most of the grain crops, has its area of greatest production in the eastern section. Figure 86 shows the production of buckwheat in the United States for 1919. The two states, New York and Pennsylvania, produced 8,476,000 bushels, or 64.5 per cent of the entire crop in 1920.

Origin and History.—The cultivation of buckwheat is not thought to be very ancient. It has been cultivated in China for 1,000 years and was introduced into Europe from northern Asia early in the sixteenth century. The crop was unknown to the ancient Greeks, Romans and Egyptians. Buckwheat was introduced early into the American colonies, for in 1626 samples of the American crop were sent to Holland. It probably originated in central Asia.

Classification.—There are three distinct species of buckwheat given by Stone (1906) as follows:

1. Common buckwheat (*Fagopyrum esculentum*).
2. Tartary or Siberian buckwheat (*Fagopyrum tartaricum*).
3. Notch-seeded buckwheat (*Fagopyrum emarginatum*).

The three species can be distinguished by their seeds. The hulls of the notch-seeded buckwheat have extended margins or wings which give the seeds an appearance of being comparatively large while in reality they are not. This species is not known in this country in a pure form but is sometimes mixed with the ordinary varieties. The seeds of Tartary buckwheat are longer than broad, are somewhat corrugated, and have wavy edges. This species is recommended for its superior hardiness. In the case of common buckwheat, the seeds are smooth and practically as long as broad. The latter species is most commonly grown in the United States.

Varieties.—There are three varieties of buckwheat commonly grown in this country, all of which belong to the *Fagopyrum esculentum* species. These varieties are Japanese, Silverhull and Common Gray. It is not an uncommon practice for growers to mix the seeds of the first two varieties for sowing.

FIG. 85.—A single plant of buckwheat. (*U. S. Dept. Agr., States Relations Service*).

Stone (1906) in New York reports the yields of these varieties in the following order: Japanese, Common Gray and Silverhull. Stewart and Atwood (1903) in West Virginia found as an average of 2 years' test that the Japanese variety yielded 31.3 bushels per acre; Silverhull, 19.6 bushels; Gray, 18.1 bushels; and Russian, 20.8 bushels. Zavitz (1915) in Ontario reports the 10-year average yield of Tartary buckwheat as 32.88 bushels per acre; Common Gray, 22.63 bushels; Japanese, 22.36 bushels; and Silverhull, 21.71 bushels.

Description.—Buckwheat is a member of the *Polygonaceae* family. However, since the seeds are used for the same purposes as the true cereals, it is usually considered a cereal.

The plant is an annual and grows erect, usually attaining a height of about 3 feet. In contrast to the root system of most grasses, buckwheat produces a tap root with but few branches, the root development being comparatively meager. There is but one stem produced from each seed, and instead of tillers there are produced strong branches at the nodes. The amount of branching depends largely upon the thickness of planting, and is less in thick stands. The leaves are alternate, triangular, 2 to 4 inches long and slightly longer than broad.

The small flowers of common buckwheat are borne in compact clusters on the end of small branches. There are two kinds of flowers produced, one with long stamens and short styles, and the other with short stamens and long styles. A single plant bears one kind but the seeds from either sort will produce plants possessing either kind of flowers. The two forms are produced in approximately equal numbers and the existence of two flower forms is thought to be of aid in cross-pollination.

Composition.—The buckwheat grain contains somewhat less protein than wheat, rye and oats, and approximately the same percentage as corn. The digestible carbohydrate content is about three-fourths that of wheat, rye and corn, and about equal to that of oats. It has more fat than wheat and rye, and about one-half as much as oats and corn. The high percentage of protein and fat in the middlings, which contain the germ, is distinctive. The composition of buckwheat and its products as given by Leighty (1919) is given in Table C.

TABLE C.—COMPOSITION OF BUCKWHEAT AND ITS PRODUCTS, POUNDS PER HUNDRED POUNDS

Buckwheat products	Water, lb.	Ash, lb.	Crude protein, lb.		Carbohydrates, lb.			Fat, lb.	
			Total	Digestible	Fiber	Nitrogen-free extract	Digestible	Total	Digestible
Grain	12.1	2.1	10.8	8.1	10.3	62.2	49.7	2.5	2.5
Flour	12.8	1.1	7.9	5.9	0.6	76.1	58.0	1.5	1.5
Middlings	12.0	4.8	28.3	24.6	4.8	42.7	38.3	7.4	6.1
Hulls	10.3	2.1	4.4	0.4	43.7	38.5	13.9	1.0	0.7
Straw	9.9	5.5	5.2	4.2	43.0	35.1	26.3	1.3	1.2
Green fodder	63.4	3.6	4.6	2.2	8.0	19.5	17.4	0.9	0.5

Uses.—The flour made from buckwheat is widely used in the United States for making griddle cakes. The middlings resulting from the manufacture of flour are highly prized for feeding cattle. The grain may also be used for stock feed, especially for feeding poultry.

The crop is used as a means of soil improvement, as a cover crop and as a honey plant. It seems that buckwheat can use relatively unavailable mineral nutrients in the soil to better advantage than the small grains, and the crop leaves the soil in a good mechanical condition.

Adaptation.—The buckwheat plant is best adapted to the northeastern part of the United States and its culture follows the mountains southward into Virginia and North Carolina. The crop does best in a cool, moist, climate, being very susceptible to cold. However, owing to its growing season of 10 to 12 weeks, it can be grown in short-season localities. At blooming time high temperature and dry weather are especially harmful, as under such conditions the flowers frequently set seed sparsely. In order to overcome these adverse conditions the crop is usually sown so that it will mature in the fall.

Buckwheat will do well on most well-drained soils. It cannot compete with the ordinary grain crops on productive soils, but on poor soils it is frequently more profitable than the true cereals. Lime is not necessary; in fact, the crop seems to prefer acid soils.

Culture

Methods of Seeding.—Buckwheat may be sown by drilling or broadcasting but the former is generally preferable. However, Stemple (1919) in West Virginia found that when 4 pecks of seed were used per acre, the average yield from drilling the seeds was 28.23 bushels per acre and from broadcasting, 28.89 bushels.

Rate of Seeding.—The rate of seeding varies from 3 to 4 pecks per acre with common buckwheat. However, in case of the Tartary species, since the seeds are relatively small, a rate of 2 pecks per acre is considered sufficient. Stemple (1919) in West Virginia found that the 4-year average yield of common buckwheat was 23.46 bushels per acre from seeding 3 pecks to the acre; 24.13 bushels from 4 pecks; 24.27 bushels from 5 pecks; and 24.52 bushels from 6 pecks. In this test the increase in yield was not profitable when the rate of seeding was greater than 4 pecks per acre.

Time of Seeding.—Buckwheat is usually sown about 10 to 12 weeks before the first killing frost in the fall. This practice will allow the crop to mature seed under the cool, moist conditions which generally prevail at this time of the year in the chief buckwheat growing sections. In New York and Pennsylvania the crop is usually seeded during the last week in June, but the date of seeding may extend from June 15 to July 15. Harvesting in these states takes place about the middle of September or shortly after.

Harvesting.—Where the topography of the land will permit, the buckwheat crop may be harvested with the ordinary grain binder. However, since the crop is commonly planted on steep, rough lands, it is most fre-

quently harvested with the grain cradle. The plants are tied in bundles and shocked in the field. The shocks are tied at the top and then left in the field until the crop is ready for storing or threshing, procedures which usually require about 10 days.

The crop is usually harvested when the first formed seeds are mature.

CHAPTER XXXV

SORGHUMS (Andropogon sorghum)

The sorghums are often important crops in the United States where the rainfall is insufficient for the production of corn. Most of the crops are produced in regions having rainfall from 15 to 30 inches annually. The production, especially of grain sorghum, has very rapidly increased.

World Production.—The information is slight in regard to the world production of the sorghums. Ball (1910) states that the crop is culti-

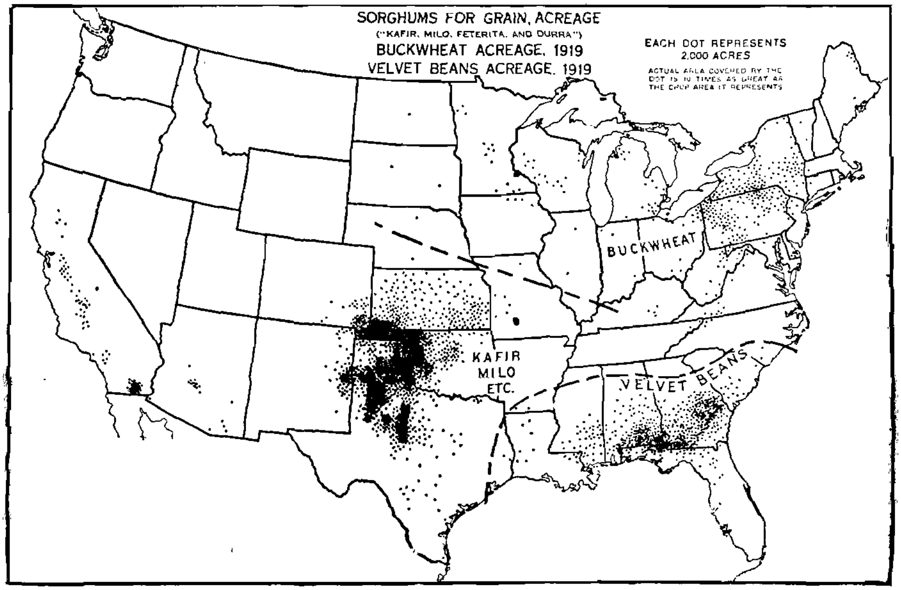

Fig. 86.—The grain sorghums are probably our most drought-resistant crops. The expansion of acreage during the past two decades in the southern Great Plains area has been extraordinary. From 1899 to 1909 the acreage in the United States increased from 266,000 to 1,635,000, or sixfold, and between 1909 and 1919 it more than doubled.

Buckwheat, which is practically confined to the Appalachian area and the Lake states, *has decreased slightly in acreage since 1909. It is peculiarly adapted to districts having* cool, moist summers and sour soils. (*U. S. Dept. Agr. Yearbook*, 1921).

vated to a great extent for grain production in Africa and India where the grain is used for human food. It is also cultivated in China and Manchuria, while in Europe the crop is not important.

In Africa and Asia the crop is cultivated chiefly for grain. In the United States it is grown for syrup, grain, forage and the manufacture of brooms.

Production in the United States.—Figures 86, 87 and 88 show the acreages of sorghums for grain, forage and syrup in the United States for 1919.

In 1919 the three states, Texas, Kansas and Oklahoma, produced 5,667,299 tons of the sorghum cut as fodder and forage. This quantity is 71.6 per cent of the entire crop cut for these purposes. These same three states, but with Kansas ranking third, produced 61,609,816 bushels of sorghum grain, or 85.5 per cent of the crop harvested for grain.

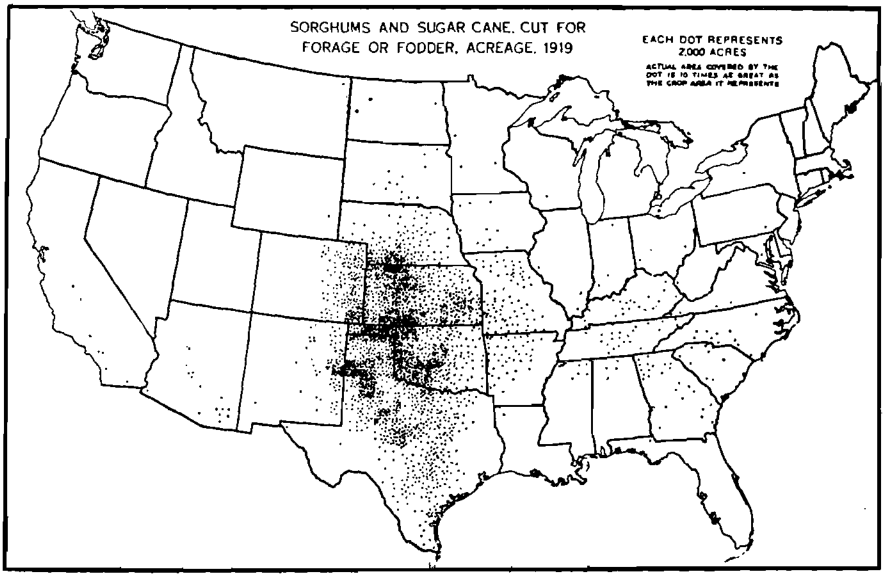

FIG. 87.—The sorghums are grown for forage much farther north than for grain; while the sweet sorghums, which are not commonly grown for grain, are frequently used for forage far to the east in the cotton belt and the corn and winter wheat regions. The acreage of sorghums for forage is larger than the acreage for grain, especially in Kansas, where some sorghum is used for silage. It is interesting to note that the average yield per acre of sorghum forage was 1.7 tons in 1919, as compared with less than 1 ton per acre for corn in this area, and 1.2 tons for corn in the entire United States. The sorghums, apparently, yield more forage per acre in this semi-arid area than corn in the humid regions. (*U. S. Dept. Agr. Yearbook*, 1921).

In the case of syrup production, the three states, Alabama, Mississippi and North Carolina, produced 17,840,000 gallons, or 53.6 per cent of the entire output of syrup.

Historical.—The cultivation of the sorghum plant, according to Ball (1910), is very ancient. It was cultivated in ancient Egypt probably as far back as 2,000 years before the time of Christ. Ball (1910) states that sorghum had an independent origin in both Africa and India. The crop was probably not introduced into Europe until about 60 A.D. Sorghum, therefore, like the corn plant, is of tropical origin.

The date introduction of the sorghums into the United States is not definitely known, but with the exception of broom corn, the sorghum

crop was not important in the United States before the middle of the last century. The crop apparently was first grown by William R. Prince, of Flushing, Long Island, New York, in 1853. In 1919 there were 3,618,998 acres grown for grain; 4,746,849 acres for fodder and forage; 487,000 acres for syrup; and 271,600 acres for broom corn.

The sorghum plant is said to have been derived from *Andropogon halepensis* which is known in the United States as Johnson grass. How-

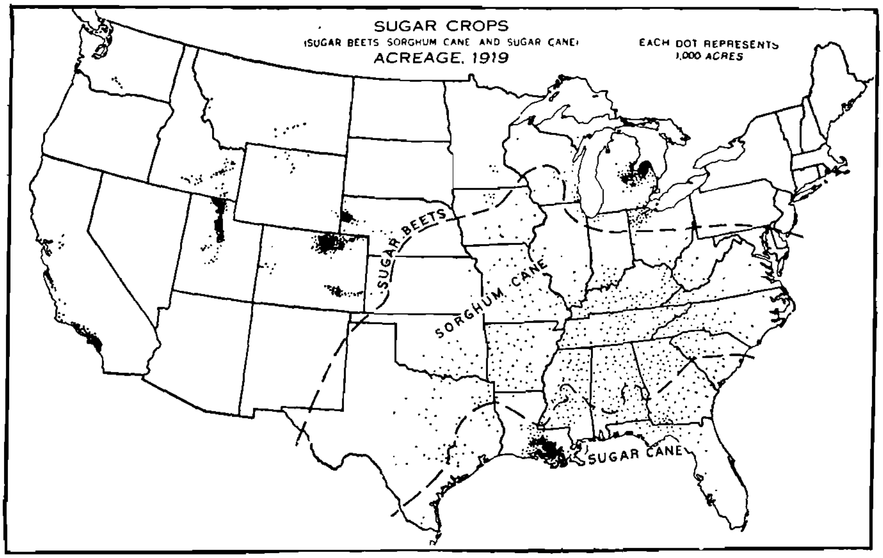

FIG. 88.—The two most important commercial sugar crops are cane and beet. The acreage of sorghum cane is greater than that of sugar cane, but the syrup is mostly made from the sorghum on the farm and does not enter into commerce. Sugar beets do not, in general, show a sufficiently high sugar content to be manufactured profitably where the summer temperature is over 72 degrees and the beets must also then compete with corn for the farmer's labor. Sugar cane is not grown commercially for sugar outside of the almost frost-free lower Mississippi Delta of Louisiana. The broad belt between the sugar beet and sugar cane areas is occupied by a thin and scattered acreage of sorghum cane. (*U. S. Dept. of Agr. Yearbook*, 1921).

ever, it has been pointed out that the wild sorghum types separate into two groups: One group includes the perennials which have rootstocks like Johnson grass; the other group includes the annuals, such as Sudan grass and Tunis grass which do not have rootstocks. The wild annual forms cross readily with sorghum, while the wild perennials cross with sorghum only with difficulty. It may be, therefore, that the original prototype of the cultivated sorghums was among the wild annual forms of *Andropogon sorghum*.

Drought Resistance.—The adaptation of sorghums, especially the grain types, to dry climates is well known; the reason for such an adaptation is less well known. Miller (1916) has shown that sorghums have twice as many secondary roots per unit of primary root as corn, although

the number of primary roots is the same. This fact may allow the sorghums to be more efficient in water absorption. Corn is not well suited to semi-arid conditions. It has also been shown that the water requirement of the sorghum plant is approximately the same as for corn. Miller (1916) has shown that sorghum, as compared with corn, has only half as much leaf area exposed for evaporation. Sorghums, therefore, are apparently less efficient in use of water on the basis of leaf area exposed. However, the sorghums, unlike corn, seem to have the ability to become practically dormant during periods of severe droughts and to renew growth, without any apparent injury, when conditions become more favorable.

Effect on Land.—Sorghums are supposed to be "hard on the land." However, the effect seems to be only temporary. The effect is most noticeable on the first succeeding crop and completely disappears in two or three years. The explanation of this detrimental effect is not known.

Sorghum Poisoning.—Numerous cases are recorded where cattle have been poisoned from feeding on growing sorghum plants, of both the sweet and grain types. The injury is caused by prussic acid, which forms under certain conditions. The prussic acid occurs to the greatest extent in the leaves and decreases with maturity. The amount is higher in plants which have been stunted by hot, dry weather. It seems that, owing to the resulting reduction in the prussic acid content, cutting the plants and allowing them to wilt eliminates the danger from poisoning. It is evident that it is inadvisable to pasture stunted sorghum plants.

Composition.—The analyses of grain sorghum and corn as shown in Table CI are taken from Ball and Rothgeb (1915), and those in regard to forage were adopted from Vinall and Getty (1920).

TABLE CI.—AVERAGE CHEMICAL ANALYSES OF SORGHUM IN COMPARISON WITH CORN

Crop	No. of samples	Constituents, per cent					
		Water	Ash	Protein	Carbohydrates	Fiber	Fat
Grain:							
Grain sorghum	268	9.52	1.70	13.01	70.95	1.53	3.29
Dent corn	86	10.60	1.50	10.30	70.40	2.20	5.00
Field-cured fodder:							
Corn	23	39.30	3.60	4.80	34.20	16.70	1.40
Kafir	20	40.00	6.20	5.90	28.40	17.70	1.80
Sorgo	11	37.40	3.10	3.90	35.00	17.80	2.80

The data indicate that the grain sorghums are higher in protein but lower in carbohydrates than corn.

SACCHARINE SORGHUMS

The saccharine or sweet sorghums, being high in sugar, have a juicy pith and produce but a small amount of grain as compared with the grain sorghums. From their introduction in 1853 into the United States

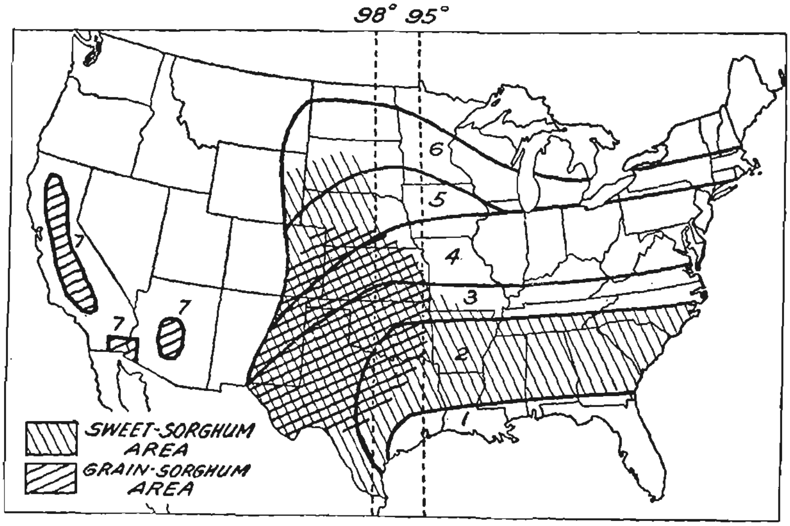

Fig. 89.—Outline map of the United States, showing the principal forage sorghum areas and the varieties recommended for each. The principal grain sorghum regions, besides the southern Great Plains, include the Salt River and Yuma valleys in Arizona and the Imperial, *San Joaquin and Sacramento* valleys in California. (*U. S. Dept. Agr. Farmer's Bul.* 1158).

until 1880 their chief use was for syrup, but since the latter date they have been grown primarily for forage.

Distribution and Description of Varieties.—The areas growing saccharine and non-saccharine sorghums are shown in Fig. 89 from Vinall and Getty (1920).

For forage purposes the recommendations in regard to varieties for the different regions as given by Vinall and Getty are as follows:

Region 1. Japanese sugar cane preferable to sorghums.
Region 2. Sumac, Orange, Honey and Gooseneck sorghums.
Region 3. Sumac and Orange sorghums.
Region 4. West of the ninety-eighth meridian, Red Amber sorghum; east of the ninety-eighth meridian, Orange sorghum.
Region 5. Red Amber, Dakota Amber and Minnesota Amber sorghums.
Region 6. Minnesota Amber, Red Amber and Dakota Amber sorghums.
Region 7. Honey, Gooseneck and Sumac sorghums.

The *Amber* variety matures in from 90 to 100 days, grows from 5 to 7 feet tall and has from 8 to 10 leaves. The well-known strains of this variety are Minnesota Amber, Red Amber, Dakota Amber and Folger's Early. The latter is said to be especially valuable for syrup production.

The *Sumac* variety, which is often known as Redtop, matures in from 105 to 120 days, and usually grows from 7 to 8 feet in height. It is much grown in the South and is well suited for syrup, silage and forage.

The *Orange* variety matures in from 100 to 125 days and is not quite so tall as the Sumac variety. It makes a large yield of forage but the heavy stalks interfere with curing of the crop. It is very suitable for syrup production.

The *Gooseneck* variety of sorghum is frequently called Texas Seeded Ribbon Cane. This name is unfortunate, as the true sugar cane is often called Ribbon Cane. The Gooseneck sorghum is a large, late-maturing variety. The plants vary from 9 to 12 feet in height; and since 20 to 50 per cent of the heads are recurved, this variety is named Gooseneck. It is primarily a syrup variety, but is also used for forage.

The *Honey* sorghum is sometimes called Japanese Seeded Cane. It is late, maturing in from 125 to 140 days, and grows to a medium height, 7 to 10 feet.

Uses.—Since 1880 the saccharine sorghums have become more important for forage than for the production of syrup. In 1919 there were 487,000 acres grown for syrup, while 4,746,849 acres were grown for forage or fodder purposes. The forage crop is very important in Texas, Kansas and Oklahoma. The crop is used as fodder, hay, soiling, silage and to some extent for pasturage.

Culture

Seed.—The selection of good seed of high-yielding, adapted varieties is just as important with sorghums as with other crops. There is a considerable difference in the time of maturity, height of growth and yielding ability of certain varieties. The differences are worthy of careful consideration. Since sorghums cross readily, it is sometimes difficult to secure pure varieties. Special attention should be given to the selection of varieties which have not become intermixed, or to the separation of the mixtures by roguing.

In addition to the selection of seeds, the storage of the seeds should be given attention. The seeds are sometimes harvested when somewhat immature but these will germinate well if stored where they can dry at once. Either improper storing of immature or damp seeds, or allowing them to become subjected to freezing weather before drying, is likely to result in greatly reduced germination.

Time of Seeding.—Sorghums are more sensitive to cold than corn, and for this reason the seeding is usually begun after corn planting is

finished. As a rule, seeding starts from 2 to 4 weeks after the earliest corn is planted. Seeding may be delayed much later if the length of the growing season will allow. However, in case of likelihood of injury from the sorghum midge, the seeding should be made as early as practicable. The midge attacks late-sown plants and destroys the seeds. According to Vinall and Getty (1920), in the southern part of the sorghum region, if forage only is desired, seeding usually starts early in March and may

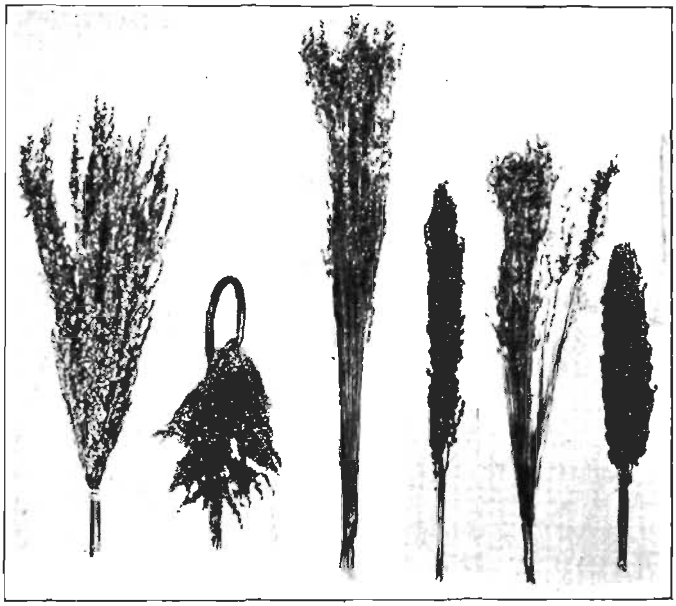

FIG. 90.—The selection of pure seeds of the sorghums for planting is important. These five kinds were obtained from a field planted with seeds bought for Orange sorghum.

continue until July 15. Farther north seeding starts about May 1. In the latitudes of Oklahoma and Kansas the best time of seeding is from May 15 to June 1.

Method of Seeding.—According to Vinall and Getty (1920), approximately 85 per cent of the sorghum crop is seeded in rows sufficiently far apart to cultivate with the ordinary corn-cultivating implements. The broadcast method of seeding is followed to a great extent when the crop is to be used for forage. Even when used for forage, there is little, if any, difference in yield, but the stalks are smaller and the hay of somewhat better quality when the crop is broadcasted. The results at the Hays, Kansas; Amarillo, Texas; and Chillicothe, Texas, field stations showed an average yield of 4.2 tons per acre from seeding in rows, and 3.83 tons per acre from close drilled seeding.

Rate of Seeding.—The amount of seed required to seed an acre will be less if the crop is seeded in rows than if sown broadcast.

Vinall and Getty (1920) state that, where seeded in rows, the yield is somewhat greater where the plants are 2 to 4 inches apart in the row than where there is more distance between plants. In the Great Plains region the proper amount to use is approximately 3 to 4 pounds of seed to the acre. In the dry regions it is seldom advisable to use more than 4 pounds of seed per acre. Where the rainfall is more plentiful, 35 to 40 inches, the quantity of seed used per acre is usually 8 to 12 pounds.

The acre yield of air-dry Red Amber fodder during a 5-year period in Kansas was 3.15 tons per acre, where the plants were 2 inches apart in the row; 2.77 tons from 4-inch spacing; 2.79 tons from 6-inch spacing; 2.61 tons from 8-inch spacing; and 2.54 tons from 12-inch spacing. The same relative results were secured over a 4-year period at Amarillo, Texas. Winters (1916) found in Texas that plants spaced 1 inch apart in 3-foot rows gave a higher yield of forage than those spaced 3, 6 or 9 inches.

In seeding broadcast or drilling, farmers generally use a rate of seeding of from 45 to 60 pounds of seed per acre. Vinall and Getty (1920) report that in Kansas and in Texas there was but little difference in yield from seeding at rates varying from 15 to 75 pounds per acre. The smaller rates of seeding produce a coarser growth and there is more likelihood of trouble from weeds. The quantity recommended west of the one-hundredth meridian in the Great Plains, is 30 pounds of seed per acre; 45 pounds between the ninety-eighth and one-hundredth meridians; and 60 to 75 pounds east of the ninety-eighth meridian. Winters (1916) secured practically the same yield of forage from drilling the seed at the rate of 2, 4 or 8 pecks per acre. Cunningham and Kenney (1917) recommend the use of 1 to 2 bushels of seed per acre under Kansas conditions.

Depth of Seeding.—The seedlings of sorghum are not so vigorous as those of corn and the other cereals. The seeds should be covered deep enough to secure sufficient moisture for germination. The depth will, therefore, depend on the kind of soil and the amount of moisture present at seeding time. The usual rate of seeding is from 1 to 2 inches. On the wet, heavy types of soil, the right depth of seeding is about 1 inch, while on sandy soils the seed may be placed 2 inches deep and sometimes deeper with good results.

Harvesting.—Where the crop is to be used for forage, the plants should be fairly mature when harvested. At this stage of growth the greatest amount of dry matter is produced, the feed is more palatable, the danger from poisoning is less, the loss in weight and quality during curing is reduced and silage made from mature sorghum is of better quality than that made from sorghum when too immature.

Sorghum for Syrup.—Sorghum when harvested for syrup production should be in the hard dough stage, as the sugar content increases until maturity, as shown by Bryan (1912).

TABLE CII.—SUGAR CONTENT OF SORGHUM AT DIFFERENT STAGES OF GROWTH

Stage of cutting	Sucrose, per cent	Invert sugar, per cent
Panicles just appearing	1.76	4.29
Panicles entirely out	3.51	4.50
Flowers all out	5.13	4.15
Seed:		
In milk stage	7.38	3.86
Doughy, becoming dry	8.95	3.19
Dry, easily split	10.66	2.35
Hard	11.69	1.81

If the crop is to be utilized for syrup, the leaves should be stripped and the heads removed before pressing, and this work is usually done before the plants are harvested. In warm weather, to prevent fermentation, the juices should be removed within a day or two after cutting. Frosted sorghum should be cut at once and put in stacks. The leaves and heads should not be removed until just before the juice is to be extracted.

The amount of syrup produced per acre will depend on the kind of sorghum planted, stage of development when cut, kind of mill used and the care exercised in manufacture. The yield varies from 60 to 300 gallons of syrup per acre, the average being from 100 to 150 gallons. A ton of cane with a three-roller mill will yield from 700 to 1,200 pounds of juice, or 8 to 30 gallons of finished syrup. The yield of sorghum per acre varies greatly, but a fair average is 8 to 10 tons of stripped sorghum per acre.

NON-SACCHARINE SORGHUMS

The non-saccharine sorghums are commonly called grain sorghums, since their principal use is for the production of grain. However, they are also used for rough forage. They are very resistant to droughty conditions and thrive exceedingly well under such conditions as compared with the other crops commonly grown for grain. The distribution of these sorghums is shown in Fig. 89.

Groups and Varieties.—The four principal types of grain sorghums are: Kafir, Milo-Durra, Shallu and Kaoliang.

The *Kafir* group includes six commercially grown varieties: White, Blackhull, Dawn, Sunrise, Red and Pink. The varieties differ chiefly in color of seeds and hulls. The heads of all varieties are erect. The plants of the kafir group as a whole have stout, short-jointed, leafy stalks. The leaves are broad and vary in number from 12 to 16 or more. The

stalks are juicy but not sweet, with the exception of the Sunrise variety which has fairly sweet juice. The Blackhull variety comprises about 90 per cent of the kafir grown in this country.

The *Durra* or *Milo-Durra* group includes six varieties which, to some extent, are grown commercially. The varieties are Standard milo, Dwarf milo, White milo, Dwarf White milo, Feterita and White Durra. The stalks are of medium size, dry and pithy; they grow from 3 to 8 feet tall and bear eight to ten rather short, narrow leaves. The heads.

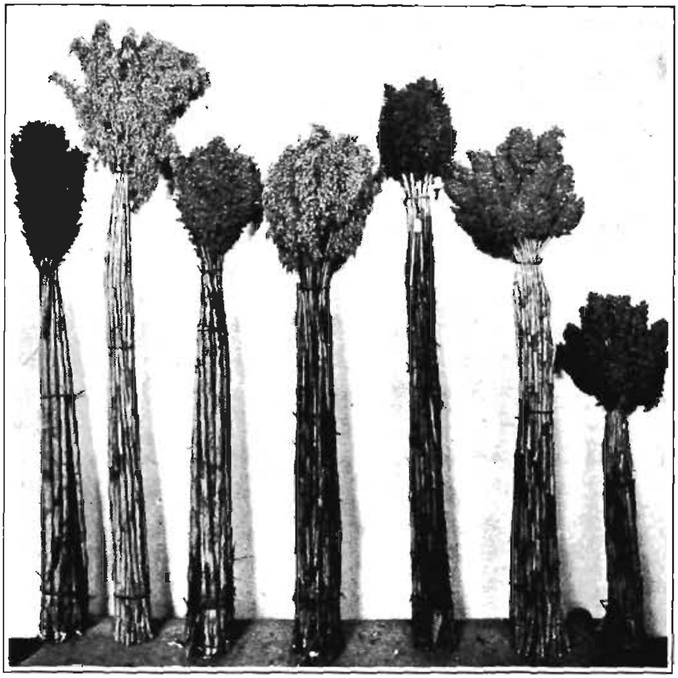

FIG. 91.—Grain sorghums. Left to right: Red kafir, Shallu, Blackhull kafir, White durra, Brown koaliang, Milo and Dwarf milo. Note differences in height. (*U. S. Dept. Agr., Cereal Investigations*).

which are either erect or pendent, are large, round or oval, and compact. Dwarf milo probably occupies a larger area than all of the other varieties combined.

Shallu is a late-maturing variety sometimes known as Egyptian wheat and Mexican Desert Wheat corn. The heads are large and open, being wide at the base and narrow at the top, and pale yellow in color. The stalks are slender and grow from 5 to 8 feet tall; the pith is neither juicy nor sweet. The value of this variety has been overestimated.

The *Kaoliang* group varieties are early maturing, and are suitable for growing in the northern sections of the sorghum regions. The heads are erect, with branches spreading but not drooping. The stalks

are slender, dry and pithy, and bear from eight to eleven, or sometimes thirteen leaves. There are both dwarf and standard varieties, which vary in height from 4 to 11 feet.

Uses.—The main reason for growing non-saccharine sorghums is for the grain. The plants may be used for forage, but they are not so desirable for that purpose as the saccharine sorghums. However, a considerable amount is used for silage purposes. The grain has about nine-tenths the feeding value of corn and the crop is grown in those sections too dry for profitable corn production. The grain is used mostly for feed, a little for human food and for making alcohol.

Culture

Seed.—The choice of adapted varieties is important in the case of the non-saccharine sorghums. It is advisable to select pure seeds which will germinate well and which are true to type. Head selected seeds are preferable to seeds selected otherwise. In making the head selections, one should consider uniformity of plants in height; uniformity of heads in size and shape; uniformity in ripening and productiveness; and in case of the milos and durras, uniformity in erectness of heads.

The seed heads should be stored in such a way as to maintain the vitality of the seeds. The seeds, after threshing, should be thoroughly cleaned and tested for germination.

Time of Seeding.—For best results the grain sorghums, which are hot-weather plants, should not be seeded too early. They should be seeded from 2 to 4 weeks after the ordinary time of planting corn. In the Panhandle of Texas and the neighboring territory, the proper time of seeding is from May 15 to June 10; and south of the Panhandle section, seeding takes place sooner. At Woodward, Oklahoma, the best seeding time ranges from May 1 to June 15.

Rothgeb (1922) found in the Texas Panhandle that Dwarf milo yielded best when seeded on the "normal" date, about May 23; Dawn kafir on the "early" date, May 10; and feterita and Manchu kaoliang on the "late" date, about June 10.

Rate and Method of Seeding.—The seeding is practically always made in rows which are usually 3 to 3½ feet apart with the plants 3 to 10 inches apart in the row. In dry seasons, with larger growing types, wide spacings give the best results, as shown by Rothgeb (1922). In favorable seasons the yields in rows 3½ feet apart were greater than the yields from those spaced 7 feet. In unfavorable years the reverse was true. It was also found in the case of Dwarf milo that the plants placed 12 inches apart in the 3½ foot rows gave the highest yield, while in 7-foot rows the largest yield was obtained when the plants were spaced 8 to 12 inches in the row.

The amount of seed required to plant an acre will vary with the spacings. Under favorable conditions it will require on the average 2 to 3 pounds of clean, viable seeds to plant an acre. The purpose for which the crop is grown will also affect the quantity of seed required. Cunningham and Kenney (1917), for Kansas conditions, recommend 4 to 8 pounds of seeds when the crop is sown in rows for grain, and double this quantity if grown for forage or silage. In dry regions less seeds should be sown than in regions of more abundant rainfall.

The crop is usually seeded with corn-planting machinery, plates being used to suit the sorghum seeds. In regions of very low rainfall, the crop is often listed instead of being surface planted. The latter method is recommended where it can be followed.

Harvesting.—Where the crop is harvested for grain production, the plants should be allowed to become fully ripe before harvesting. The varieties which shatter badly may be cut when they are somewhat immature. In case the crop is to be utilized for silage, harvesting should take place when the seeds are in the hard dough stage.

The plants are usually harvested by one of three methods: (1) heading by hand; (2) heading with a grain header; and (3) cutting with the corn binder. In case of the first two methods, the stalks are left standing in the field, while in the latter case the crop is shocked like corn. Where the crop is grown on a large scale cutting with a corn binder is usually the most preferable method. The grain may be removed from the heads by running them through the ordinary threshing machine.

BROOM CORN

Broom corn, a type of sorghum, is of little value for forage, but the matured seeds are often used for poultry and stock food. The crop is almost entirely grown for the elongated branches of the panicle, which are used for the manufacture of brooms. Broom corn is more like shallu and kaoliang than like the other sorghums.

Kinds.—There are two kinds of broom corn, the Standard and the Dwarf. They differ mainly in the height of plant and in the length and texture of the brush. The Standard type grows from 10 to 14 feet tall, and the brushes are usually from 18 to 24 inches long. The fiber is ordinarily round and pliable but not quite so fine as that of the Dwarf type. The Standard broom corn constitutes about one-third of the crop.

The Dwarf broom corn grows from 4 to 6 feet tall and produces brushes varying in length from 15 to 20, or sometimes 24 inches long. When the fiber of the brush is fine and of good quality, it is used in the manufacture of whisk brooms and brushes. About two-thirds of the broom corn crop of the country is of the Dwarf variety.

Production.—Broom corn may be produced satisfactorily wherever corn does well. However, since the quality of the brush is as important as the yield, climatic conditions must be favorable and the soil must be uniform in productiveness. Care should be taken to secure good seeds; and it will usually require from 2 to 3 pounds to sow an acre when planted in rows 3 to 3½ feet apart. Standard broom corn, which is generally seeded 2 to 3 weeks after corn planting, is seeded in rows 3½ feet apart and the plants left 3 to 5 inches apart in the row. The Dwarf type is generally seeded in rows 3 feet apart and the plants are left 2 to 4 inches apart in the row. A uniform stand is important as this will determine to some extent whether the brushes will be uniform.

The brush should be harvested when the natural green color extends from the tip of the fiber to the base and center of the head. This stage will be from the time the flowers are falling to the time of the milk or early dough stage of the seeds. The methods of harvesting Standard and Dwarf broom corns are different. The Standard broom corn is bent over or tabled and the brush is cut off, while the Dwarf is jerked or pulled from the standing stalks.

After harvest the brush is taken to the drying shed where the brush of poor quality is separated from that of good quality. The crop is then threshed and placed under shelter to cure. Rapid curing is necessary in order to maintain the desirable green color. If grading is not done before threshing, it should be done after the curing is completed. The brushes are then made into bales weighing from 300 to 400 pounds each, and stored in a dry, dark place until ready to market.

SUDAN GRASS

Historical.—Sudan grass (*Andropogon sorghum sudanensis*) was introduced into the United States from Khartum, Sudan, in 1909 through the efforts of C. V. Piper, of the Office of Forage Crop Investigations, United States Department of Agriculture. It is probably a native of Egypt where it is grown and called "garawi." Sudan grass was immediately successful in the United States. From the 8 ounces of seed obtained in the original importation a crop was developed which in 1918 was worth $10,500,000.

Description.—Sudan grass is an annual hay plant belonging to the sorghum family. The stems are slender and average 3 to 5 feet in height when the crop is planted broadcast or drilled, and 6 to 9 feet when grown in rows. The plants have numerous rather soft leaves, loose, open panicles, numerous tillers, rarely any branches and no rootstocks. It may be said that it is not unusual for a single plant to bear as many as 100 tillers. The production of tillers is most apparent after the first cutting and as a result the hay of the second cutting is of finer texture

than that from the first. Sudan grass closely resembles Johnson grass but the latter is a perennial. Under favorable conditions Johnson grass grows from 3 to 4 feet in height and has few, narrow, rather harsh leaves with thick white midribs. The panicles are loose, open and often drooping, there are but few tillers and there are numerous aggressive rootstocks which make the plants difficult to eradicate.

FIG. 92.—Plant of Sudan grass. (*U. S. Dept. Agr. Farmers' Bul.* 1254).

Sudan grass, which has been classed as a "grass sorghum" because of its absence of rootstocks, is probably the wild prototype of the cultivated sorghums and crosses readily with them.

Adaptation.—Sudan grass, like the other sorghums, thrives best in a warm climate and, under favorable conditions, as many as four cuttings may be obtained in one year. In drought resistance it is equal but not superior to the best sorghums, but it does best when abundant moisture is present.

Sudan grass is not exacting in its soil requirements, but of course thrives best on a rich soil. It may be said that Sudan grass does better on poor soils than most hay crops. The crop is as tolerant of acid and alkali soils as the other sorghums. Well-drained soils are essential as cold, wet soils often result in failures.

Regions.—Sudan grass is known in nearly every part of the United States and its relative importance in different regions of the country is shown in Fig. 94. In region 1, Sudan grass reaches its greatest importance because of the need of a better hay grass in this region. In region 2, Sudan grass does about as well as in region 1 but timothy, clover and alfalfa do so well that Sudan grass serves merely as a catch crop. In region 3, Sudan grass is superior to timothy and clover where the rainfall is low. Its chief competitors are alfalfa, sorghum and millet. Alfalfa is preferred to Sudan grass only under such favorable locations as river and creek valleys and where irrigation is possible. In region 4, Sudan grass yields well and is used to a large extent to supplement alfalfa. In region 5, Sudan grass is successful only in limited areas, due either to low temperature or insufficient rainfall. In region 6, Sudan grass is usually a failure largely on account of the injury to the foliage caused by

red spot or sorghum blight. In region 7, Sudan grass is not profitable on account of the cool summers and short growing seasons.

Uses.—Sudan grass makes a hay of excellent quality and the yields are good. Southward from the central part of the United States, two

Fig. 93.—Johnson grass often becomes a serious weed and it is important that it should not be an impurity in Sudan grass seeds. Johnson grass seeds on left and Sudan grass seeds on right.

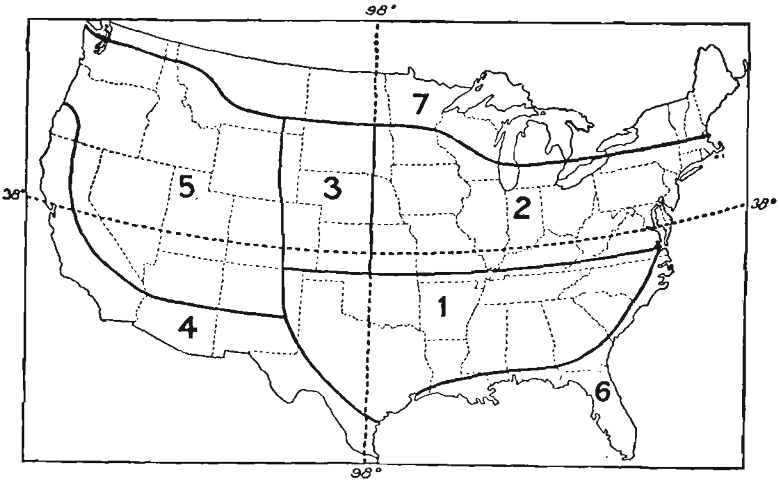

Fig. 94.—Outline map showing the forage value of Sudan grass in different parts of the United States. (*U. S. Dept. Agr. Bul.* 981).

cuttings may be secured, and sometimes as many as four. The first cutting is usually produced in from 60 to 80 days after seeding, the second cutting is usually ready in about 45 days after the first one, while the third one requires 50 to 55 days after the second. Sudan grass makes a rapid growth and, therefore, is adapted for use as a catch crop.

Its chief competitors as a forage plant are sorgo and millet. The comparative yields of these crops as reported by Vinall and Getty (1921) are shown in Table CIII.

TABLE CIII.—COMPARATIVE YIELDS OF SUDAN GRASS, MILLET AND SORGO, SEEDED BROADCAST OR IN CLOSE DRILLS

Location of test	Yield of cured hay per acre, tons		
	Sudan grass	Millet	Sorgo
Southern Great Plains	3.33	1.83	4.64
Central Great Plains	1.78	1.51	2.89
Northern Great Plains	1.49	1.89	2.24
Timothy and clover region	2.80	2.52	6.06

Sudan grass is also valuable for soiling, silage and summer pasturage. Like Johnson grass, it is less likely than the larger sorghums to contain sufficient amounts of prussic acid to be dangerous. So far as known, only three cases of poisoning by Sudan grass have been reported. Sudan grass has also been seeded in mixture with cowpeas and with soybeans. According to Vinall and Getty (1921) the average yield per acre from Sudan grass alone was 2.67 tons; from Sudan grass and soybeans, 2.96 tons; and from Sudan grass and cowpeas, 2.93 tons.

Feeding Value.—Chemical analyses of Sudan grass show that it has about the same composition as common foxtail millet and timothy.

CULTURE

Time of Seeding.—Sudan grass should not be seeded until the soil is warm; that is, about 2 weeks after the normal date for planting corn. When the crop is seeded too soon, the early growth is usually slow and the stand is poor. In the extreme South the best time of seeding is between April, and May 1; in the latitudes for Oklahoma and Kansas, between May 1 and June 15; and in the latitudes for Nebraska and South Dakota, between May 15 and June 15. From Kansas south good yields of hay may be secured by seeding July 1 or even later.

Vinall and Getty (1921) report the results of tests as shown in Table CIV. The tests in the southern section were conducted in California, Texas, Louisiana, Mississippi, Georgia and Florida; in the middle section they were conducted in Kansas, Oklahoma, Texas, Tennessee, Virginia and Maryland; and in the northern section they were conducted in Minnesota and South Dakota.

TABLE CIV.—AVERAGE YIELDS OF SUDAN GRASS HAY FROM DIFFERENT DATES OF SEEDING IN VARIOUS PARTS OF THE UNITED STATES.

Location of test	Average yields of cured hay (tons) per acre from plantings made on							
	Apr. 1	Apr. 15	May 1	May 15	June 1	June 15	July 1	July 15
Southern section.	3.21	3.18	2.83	2.76	2.69	2.32	1.83	1.33
Middle section...	1.14	1.45	2.15	2.27	2.28	2.20	1.66	1.35
Northern section.	....	....	3.75	3.71	3.82	3.63		

Method of Seeding.—Sudan grass may be drilled or sown in rows of convenient widths. The latter method is often followed under dry farming conditions, while under humid conditions and under conditions of irrigation, drilling is practiced, especially when the crop is intended for hay. A hay of better quality, because of the smaller stems, is usually secured from drilling rather than from seeding in rows. For seed production the crop is generally seeded in rows.

The yields of Sudan grass hay from different methods of seeding as reported by Vinall and Getty (1921) are shown in Table CV.

TABLE CV.—AVERAGE YIELDS OF CURED SUDAN GRASS HAY FROM DIFFERENT METHODS OF SEEDING

Location of test	Yields per acre, in tons		
	Close drilled or broadcasted	18 to 24-in. rows	34 to 44-in. rows
Humid region..........................	3.42	3.80	3.61
Dry regions (not irrigated)................	1.81	1.95	1.72
Dry regions (irrigated)....................	4.93	5.24	4.64

Rate of Seeding.—Sudan grass has been seeded at rates varying from 10 to 40 pounds per acre. However, the best rate of seeding cannot be definitely stated, since the plants tiller very profusely, especially when the stands are thin. The rate generally recommended for drilled or broadcasted seedings under humid conditions is 20 to 25 pounds per acre; under irrigation, 15 to 20 pounds; and in dry sections without irrigation, 12 to 15 pounds. If the ordinary grain drill is set to sow 2 pecks of wheat per acre, about 20 to 25 pounds of Sudan grass seed will be sown.

For seeding in cultivated rows 36 to 44 inches apart, the quantity of seed required will be 2 to 4 pounds per acre, while in 18- to 24-inch rows, 4 to 6 pounds of seed per acre will be necessary.

The yields from different rates of seeding as reported by Vinall and Getty (1921) are shown in Table CVI.

TABLE CVI.—AVERAGE YIELDS OF DIFFERENT RATES OF SEEDING BROADCAST OR IN CLOSE DRILLS

Location of test	Hay yields in tons per acre when seeded at following rates per acre				
	10 lb.	15 lb.	20 lb.	25–30 lb.	35–40 lb.
Humid regions	....	2.91	2.95	3.02	2.87
Dry regions (not irrigated)	....	3.37	3.32	3.19	3.22
Dry regions (irrigated)	5.34	4.88	4.98	4.46	4.46

Harvesting.—The preferable time for cutting Sudan grass for hay is from the time the plants begin to head until they are fully headed. If several cuttings are desired, harvesting is done slightly sooner than if a subsequent cutting is not desired. On account of the numerous tillers which mature considerably later than the primary stem, Sudan grass does not deteriorate so much as many other grasses from cutting late. When the crop is to be used for seed, it is cut with the ordinary grain binder when the seeds are about mature and then allowed to cure in shocks.

Seed Production.—Under dry conditions when the crop is not irrigated and under humid conditions the yield of seed is greater when the crop is grown in cultivated rows. However, under irrigation the yield of seed is greater when the crop is broadcasted or seeded in close drilled rows. The yields of seed as reported by Vinall and Getty (1921) are shown in Table CVII.

TABLE CVII.—AVERAGE YIELDS OF SUDAN GRASS SEED UNDER DIFFERENT METHODS OF SEEDING

Location of test	Yield of seed in lb. per acre		
	Broadcast or in close drills	Cultivated rows	
		18 to 24 in. apart	36 to 44 in. apart
Humid regions	328	417	354
Dry regions (not irrigated)	206	285	271
Dry regions (irrigated)	1,123	966	905

CHAPTER XXXVI

COTTON (Gossypium spp.)

Cotton is the most important fiber crop of the world. The plants which produce it have been known and highly valued from time immemorial. In India, China, Egypt, and in America, cotton was cultivated and its fiber made into fabrics prior to the advent of the Christian Era. It is the most important cash crop of the United States. The soil and climatic conditions of the southern states are particulary suited to the production of the crop.

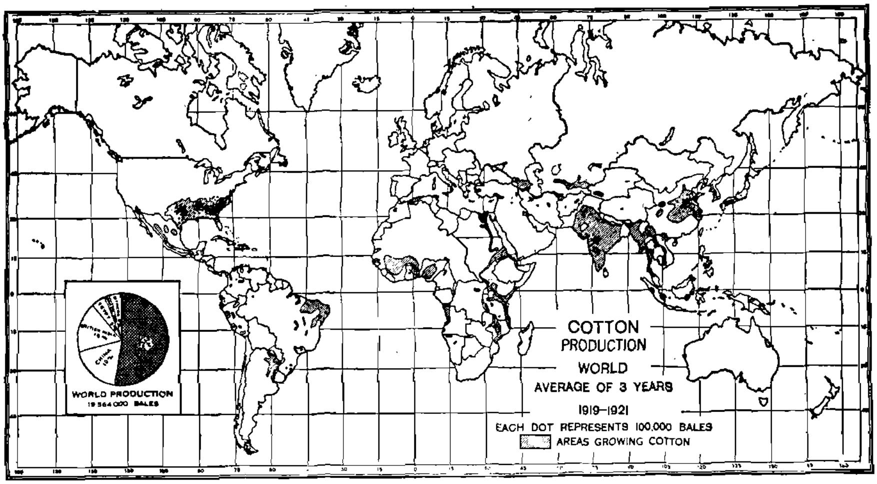

FIG. 95.—The United States produces over half of the world's cotton crop. The total crop of China is placed second by various estimates. In commercial production, India is second. Cotton is grown in many parts of Africa and South America, but only in small quantities. Australia also grows a small quantity. Cotton requires a long season of warm weather for growth and proper maturity. Its latitudinal limits north and south fall between 35 and 45 degrees, depending upon elevation and other conditions affecting the length of the frostless season. (*U. S. Dept. Agr. Yearbook*, 1921).

World Production.—Figure 95 shows the world production of cotton for the 3-year period, 1919 to 1921.

Production in the United States.—Figure 96 shows the acreage and production of cotton for the United States in 1919.

The annual yield of cotton for the United States as a whole for the 5-year period, 1910 to 1914, was 14,259,000 bales, with an average acre yield of 192.1 pounds of lint; during the period, 1915 to 1919, the average annual production was 11,481,000 bales and the average acre yield was 161.5 pounds of lint.

The five states Texas, Georgia, South Carolina, Mississippi and Alabama, during the 10-year period, 1911 to 1920, produced, on the average, 9,279,600 bales of cotton or 71.1 per cent of the total crop.

Cotton ranks second in value of crops grown in the United States, being exceeded in value by no crop except corn. It represents approximately 16 per cent of the total value of all crops produced in this country and occupies only 9 per cent of the total acreage in crops.

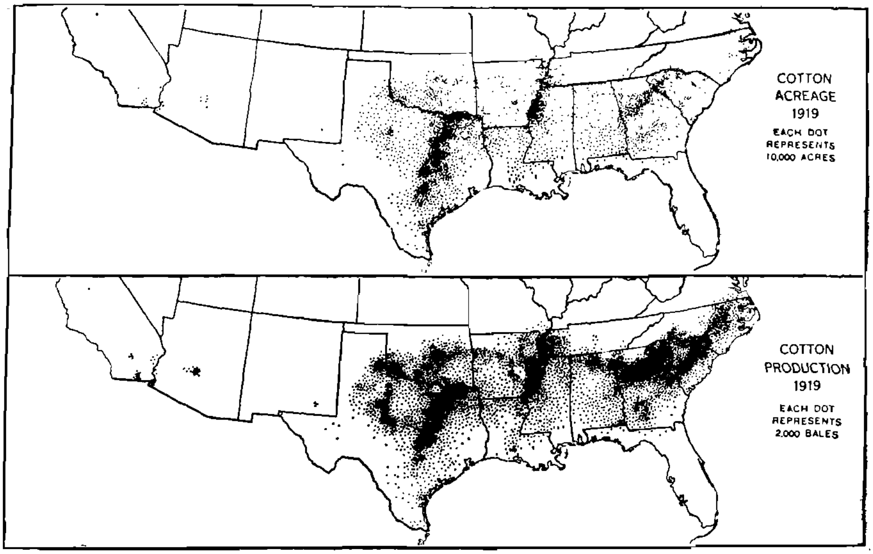

FIG. 96.—The northern boundary of the cotton belt is approximately the line of 200 days' average frost-free season and 77 degrees mean summer temperature, the southern boundary that of 11 inches autumn rainfall, because wet weather interferes with picking and damages the lint. This southern boundary is now moving northward, as the milder winter temperatures near the Gulf and longer season permit increased injury by the boll weevil. The western boundary of cotton production without irrigation is approximately the line of 23 inches average annual rainfall. (*U. S. Dept. Agr. Yearbook*, 1921).

Historical.—The early history of cotton is somewhat obscure. It is known that it has been grown in tropical countries of both hemispheres for ages. India appears to have been the center of an important cotton industry as early as 1500 B.C. The cultivation of cotton spread from India to Egypt, and thence to Spain and Italy. The Egyptians, Greeks and Phoeniceans had reached an advanced stage in spinning and weaving cotton fiber long before the Christian Era.

England began the manufacture of cotton cloth in the seventeenth century and is now the largest cotton-manufacturing country of the world.

Columbus found cotton growing in the West Indies. It was also found in Mexico and Peru by Cortez and Pizarro, and cotton cloth was found in the ancient tombs of the Incas. Regardless of the fact that

the crop was being grown on the American continents at the time of the discovery, cotton did not become of importance in the United States until the latter part of the eighteenth century when the invention of the cotton gin by Whitney in America and the power loom by Cartwright in England gave an impetus to the cotton industry. Prior to this time, cotton was grown only to a limited extent in Virginia and the Carolinas. At the present time ten of the southern states annually produce about four-fifths of the world's supply of raw cotton. It is the principal source of farm income in at least six of the southern states, and comprises about one-sixth of the total value of all crops grown in the United States.

Classification.—There are seven commonly recognized species of cotton, as follows:

1. *Gossypium Barbadense,* the long-staple Barbadoes, Sea Island, Egyptian and Peruvian varieties.
2. *Gossypium herbaceum,* the varieties of India, Siam, China and Italy.
3. *Gossypium hirsutum,* the American upland varieties.
4. *Gossypium arboreum,* found in Ceylon, Arabia and South America.
5. *Gossypium Peruvianum,* the native varieties of Peru.
6. *Gossypium Tahitense,* found in Tahiti.
7. *Gossypium Sandwichense,* found in the Sandwich and adjacent islands.

A number of other species of cotton have been described but the preceding classes include practically all of the cotton of commerce.

There are only two species of cotton grown commercially in the United States—American upland (*G. hirsutum*) and Sea Island (*G. Barbadense*). The American upland varieties have white flowers which turn rose, pink or red on the second day of blooming. The flowers of Sea Island cotton are yellow with a purple spot at the base of each petal. The flowers are surrounded by deeply fringed bracts which correspond in number to the locks in the bolls. In Sea Island cotton there are usually three bracts while in the upland varieties four and five are the prevailing numbers. Before they open the bracts together with the flower buds are called "squares."

Varieties of Upland Cotton.—American upland cotton is subdivided into short-staple and long-staple groups. There are a great many named varieties of upland cotton and most of them differ only in a few characteristics. Duggar (1899) in Alabama has classified the upland varieties of cotton into seven groups as follows:

1. *Cluster Type.*—The plants of this type are slender with long basal limbs and extremely short middle and upper fruiting limbs. The bolls are small and grow in clusters; the seeds are small to medium and thickly covered with fuzz. Examples: Jackson and Welborn.

2. *Semi-cluster Type.*—The plants of this type are similar to the cluster type but have shorter basal limbs; the bolls are borne close together, but not in clusters; and the seeds are of medium size. Examples: Hawkins and Herndon.

3. *Rio Grande Type.*—The plants of this type have slender, long, pointed limbs; the leaves are small with narrow, sharp-pointed lobes; the bolls are small to medium; the seeds are small, dark, smoky brown and almost without the short fuzz common to other varieties; they have a large proportion of lint, usually 35 to 40 per cent of the weight of the seed cotton. Example: Peterkin.

4. *Short Limb.*—In this type the plants are small and well branched; the limbs are short; the bolls small; the seeds are medium in size and covered with fuzz of different shades; the plants produce short fiber. Examples: King and Lowry.

5. *Big Boll Type.*—The plants of this type are characterized by extremely large bolls, 60 or fewer in number, often producing a pound of cotton. The plants are late maturing and large; the seeds are large and usually covered with a thick, whitish fuzz. Examples: Triumph and Russell.

6. *Long Limb Type.*—In this type the plants are extremely large and have a ragged appearance. Examples: Ellis and Gunn.

7. *Long-staple Upland Type.*—The plants of this type are tall and of semi-cluster type; the bolls are slender; and the seeds are densely covered with white fuzz. The chief distinguishing characteristic of the group is the length of the lint which varies from $1\frac{3}{16}$ to $1\frac{3}{8}$ inches. Examples: Griffin and Columbia.

Sea Island Cotton.—The culture of this species in the United States is restricted to the coast regions of South Carolina, Georgia, Florida and a few neighboring islands. The plants grow very tall and have long slender branches. The petals are yellow each with a red spot near the base. The bolls are narrowly ovoid, the fiber long and silky and the seeds naked and black. The fiber is spun into fine yarns and used largely in the manufacture of laces, cambric and fine hosiery.

Superior Varieties.—Since cotton is very sensitive to such factors as length of growing season, soil type, and moisture supply, many varieties have been developed particularly adapted to more or less local conditions. In sections where storms are prevalent, varieties have been developed which hold their lint well even in severe wind storms. Early varieties have been developed for the northern part of the cotton belt, and in recent years, for use under boll-weevil conditions. The following list of varieties has been recommended by agronomists and plant breeders in the cotton states. Most of them were taken from the report of the nineteenth annual convention of the Association of Southern Agricultural Workers.

For states not represented at this convention, experiment station bulletins and reports have been used as sources of information.

The superior cotton varieties for the different states follow:

Alabama: Cook, Cleveland, Covington-Toole, Poulnot and Layton.

Arkansas: Trice, Rublee, Cleveland, King's Improved and Simpkin's Prolific.

Georgia: Covington-Toole, Lewis No. 63, Webber No. 49. For the Coastal Plain section, Sea Island. For the limestone valleys and uplands, College No. 1 and King's Improved. For the Piedmont section, Cleveland Big Boll, Cook's Improved, Sunbeam, Webber No. 49 and Columbia.

Louisiana: Cleveland Big Boll, Brown No. 1, Express, Allen's Long Staple, Simpkin's Prolific, Triumph, Toole, Moneymaker and Bank Account.

Mississippi: Wannamaker, Cleveland, Cleveland Big Boll, Miller, Triumph, Express, Foster No. 120 and Trice.

North Carolina: Wannamaker, Cleveland, Cook's Improved, Mexican Big Boll, Lone Star, Webber No. 49 for the Coastal Plain section; and King's Improved, Trice, Simpkin's Ideal, Cleveland Big Boll and Mexican Big Boll for the Piedmont section.

Oklahoma: Triumph, Rowden, Lone Star and Acala.

South Carolina: Cleveland, Simpkins, Broadwell, Toole, Webber No. 49, Cook's Double Limb, Brown No. 1, Covington, Petway, Poulnot and Columbia.

Tennessee: Trice, Cleveland Big Boll and Express.

Texas: Triumph, Rowden, Alabama Wonder, Bank Account and Burnett.

Virginia: Trice and King's Improved.

Botanical.—Cotton belongs to the *Malvaceae* or Mallow family and the genus *Gossypium*. One of the chief distinguishing features of the Mallow family is that the stamens are united to form a tube around the pistil; and the anthers are one-celled. Okra and a few cultivated flowers, such as hollyhocks, hibiscus and althea, are also members of this family. From the industrial standpoint, cotton is by far the most important member of the Mallow family.

The genus *Gossypium* includes all species of both wild and cultivated cottons. The plants in this genus have branching stems, petioled and palmately lobed leaves, and showy flowers each with five sepals united into a cup-like calyx and five petals of whitish or yellowish color which often turn pink with age. The seeds are angular and usually woolly but rarely naked. The stigmas are congested and usually number from 3 to 5, equal to the number of locks in the mature boll.

The plant has a tap root with secondary roots which branch laterally from the primary root. The tap root may extend to a depth of several feet under favorable soil conditions but in heavy clay soils it may be only a few inches long. The secondary roots grow close to the surface of the soil and completely fill the soil area immediately around the plant with a network of lateral roots

The thick leathery capsule which contains the seeds and lint of the cotton plant is called the "boll." The bolls are ovoid in shape and pointed at the apex. When the bolls mature, they open, exposing the seed cotton.

The Seeds.—Within each lock of cotton there are six to ten seeds each covered with lint or long hairs. In upland cotton the seeds are covered with fuzz or short hairs after the lint is removed. This fuzz may be grayish, brownish or green in color.

FIG. 97.—An excellent cotton plant, which is ready for the picker. (*Courtesy Dr. R. Y. Winters*).

The seeds of Sea Island cotton are black and free from fuzz when the lint has been removed. The proportion of seed in lock cotton (cotton as picked from the bolls) is usually about two-thirds of the total weight. It takes approximately 1,500 pounds of seed cotton to make a bale of 500 pounds of lint. The remainder, 1,000 pounds, contains about 31 pounds of nitrogen, 13 pounds of phosphoric acid, 12 pounds of potash and 2.5 pounds of lime and is, therefore, very rich in fertilizing constituents. The seed of upland cotton weighs 33 pounds to the bushel and that of Sea Island 44 pounds.

The Lint.—Each cotton fiber is a tubular hair-like cell 0.001 to 0.025 of an inch in diameter. Its length varies from 0.80 to 0.95 of an inch in the short-staple upland varieties to 0.90 to 1.5 inches in long-staple upland kinds. The fiber of Sea Island cotton is usually from 1.5 to 2 inches in length. If a cotton fiber is examined under the magnifying glass, it will be found to be somewhat compressed and irregularly twisted. The amount of twist in cotton determines, to a large extent, its spinning quality and

hence greatly affects its value. The degree of twist is to a large extent governed by the stage of development of the fiber. The immature fibers have very few twists, while mature fibers may have as many as 500 twists to the inch. The strength of cotton fibers varies according to development, fineness and variety. Williams (1906) of North Carolina found the average breaking strength of twelve different varieties to be 6.83 grams. The cotton fiber is stronger in proportion to its size than flax or wool, but not so strong as silk and hemp.

Uses.—Cotton is grown chiefly for its fiber, which is used in the manufacture of cloth and thread. However, there are a number of by-products which represent a large part of the value of the crop. The seeds are used in the manufacture of feeds for animals, fertilizers and in the making of oils.

In the manufacture of oil the seeds are first ground; then the hulls are separated and the oil is extracted from the meats. A ton of cottonseed will usually yield 800 pounds of hulls, 750 pounds of seed cake and 300 pounds of oil. The remainder of the ton represents loss by evaporation and waste products.

Cottonseed oil has about the same composition as olive oil and is used for making salads, for cooking and for lubrication. It is also manufactured into oleomargarine, soaps and paints. The cottonseed cake is ground into cottonseed meal and used for feed or fertilizer. The meal makes a highly concentrated feed which contains 25 to 45 per cent protein and 10 to 15 per cent fat. It is largely prized as a cattle feed and is used to some extent for horses and sheep. It is toxic to hogs and will cause death if fed in large quantities. It also causes digestive disorders in poultry and young animals when fed in large quantities. High-grade cotton seed meal contains 7 per cent nitrogen, 3 per cent phosphoric acid and 2 per cent potash and is used in considerable quantities in the fertilizer industries, particularly when cattle feeds are cheap.

Cottonseed hulls are used as a low-grade roughage for cattle and in the manufacture of paper and fiber board. They are also used to a limited extent in the manufacture of fertilizers.

Cotton Culture.—The general cultivation of the cotton crop is much the same as that of corn. For best results the crop must grow rapidly from the start and cultivation must be such as to encourage quick growth and early maturity.

Preparation of the Seedbed.—The time of plowing for cotton is governed to a large extent by the type of soil. On stiff soils and soils covered with much vegetation, plowing in the fall or early winter is desirable. If plowing is done in the fall or early winter, a small quantity of the subsoil may be brought to the surface as a deep seedbed is desirable. However, when lands are plowed in the spring, it is not desirable to bring the inert subsoil to the top.

Sandy soils which are not covered with vegetation need not be plowed until spring, as they are easily compacted and often have to be plowed a second time if plowed too early. If the land has much vegetation on it, such as corn or cotton stalks, these should be cut up with a stalk cutter or disked into the soil before plowing. An abundance of organic matter is desirable in case of cotton soils, and cropping systems which bring about this condition are advised. Good drainage is absolutely essential for the economic production of cotton, and the crop should never be planted on wet, water-logged soils. In order to facilitate drainage in the early part of the growing season, cotton is usually planted on low ridges thrown up by a one-horse turn plow. The ridges are commonly thrown up a week or 10 days before planting time so that the soil may become compact. Just before planting time these ridges are run over with a smoothing harrow or similar implement to freshen the top soil and then the seeds are planted in the center of the ridges.

Fertilizers and Their Application.—Owing to the great variety of soils and the great variation in the productivity of soils, even of the same type, it is impossible to give a fertilizer analysis or to state the amount which will give best results under all conditions. However, for the production of good yields of cotton there must be a liberal quantity of readily available plant nutrients in the soil. For this reason rather heavy applications of commercial fertilizer are generally used throughout the cotton belt. A common application is 400 to 600 pounds of a fertilizer carrying 2 to 4 per cent nitrogen, 8 to 10 per cent phosphoric acid, and 2 to 6 per cent potash. In soils which have been made rich in nitrogen by the use of organic matter and legumes, the nitrogen may be entirely omitted, as an overbalance of nitrogen has a tendency to delay the maturity of the crop and to cause a too small production of bolls in proportion to the size of the plant.

In soils rich in potash the amount of potash in the fertilizer may be reduced, but the phosphoric acid is practically always advisable. There are two methods used in applying fertilizer to the cotton crop: (1) distributing in drills and then bedding and planting over these drills; and (2) distributing both the seeds and fertilizers with a machine at one operation. Regardless of the method used, the fertilizer should not come in direct contact with the seeds as it may reduce germination. When the fertilizer is distributed before planting, it is a good plan, in order to mix the fertilizer with the soil, to run a cultivator through the drill furrow before ridging. When heavy applications of fertilizer are made, Newman (1903) of South Carolina recommends that a small application be made in the drill and the remainder applied broadcast.

Planting.—Cotton should not be planted until at least 2 weeks after the last killing frost date of the section. If planted in a cold soil the seeds are likely to rot rather than germinate. However, the crop should be

planted as soon after this time as possible. Early cotton, in most cases, gives higher yields than late cotton, and in the boll weevil territory the early cotton is not as subject to the ravages of this pest as the late cotton.

Only high germinating, heavy cotton seed should be planted. Investigations show that heavy seeds give higher yields than light or unseparated seeds. One bushel of good cotton seed is sufficient to plant an acre. This amount is more than is required for a good stand, if all seeds germinate and grow; but it is considered a good practice to plant an excess quantity of seed and chop with a hoe to the proper stand. The seeds are drilled in rows 3½ to 4 feet apart and the plants are left 12 to 30 inches apart in the drill, according to the productivity of the soil. The seeds are covered 1 to 2 inches deep.

FIG. 98.—Cotton picking. (*U. S. Dept. Agr., Bu. Agr. Econ.*)

Cultivation.—The main objects in cultivating cotton are to keep the weeds out and to keep the soil stirred on top until the plants have become large enough to shade the ground completely. Deep cultivation is not advisable. The first cultivation may be given with a section spike-tooth harrow running across the rows as soon as the cotton is up and well established. Subsequent horse cultivations may be given with any type of cultivator which kills weeds and stirs the soil thoroughly between the rows. After the first cultivation with the cotton cultivator, the crop should be hoed to kill out the weeds between the plants in the drill and to chop out the plants to a proper stand. If the horse cultivations given thereafter are frequent and thorough, it is not usually necessary to hoe the crop a second time. When the crop is "laid by" it is very important to have the

cotton field free of weeds and this condition should be attained even if more hand work is required.

Harvesting.—Practically all of the cotton crop is picked by hand. Many mechanical cotton pickers have been invented, but up to the present time these machines have not proved practical. The crop does not ripen uniformly and the picking covers a period of several months, since the cotton plant continues to produce flowers and bolls until it is killed by frost. The picking season usually begins in September and runs through December. Picking is a laborious task and the crop is usually limited to the acreage that can be picked. The average cotton picker can gather from 150 to 200 pounds of seed cotton a day, if the crop is good and the open bolls are abundant.

After the cotton is picked, it is hauled to the gin where the lint is removed from the seed. The lint is then compressed into bales of 500 pounds each and is marketed in this form.

SOME INSECT PESTS

Mexican Boll Weevil.—The Mexican boll weevil (*Anthonomus grandis*) entered the United States from Mexico in 1892 and since that time has spread rapidly and caused enormous destruction to the cotton crop. In the adult stage the boll weevil is a beetle about one-fourth of an inch long, varying from one-eighth to one-third of an inch, with a breadth about one-third the length of the body. This measurement includes the snout which is about one-half as long as the body. The recently emerged weevils are light yellowish in color but in the course of a few weeks they change to gray or nearly black.

The weevils pass the winter in the adult stage, emerge from hibernation just after the cotton has broken through the ground, and continue until the plants begin to square. The beetles feed only during the day, their food being the foliage, especially the tender terminals. When the squares begin to form, the female beetle deposits eggs in them. In each cavity made by the beetle is deposited one egg which hatches in about three days. The larvae or grubs begin to feed on the embryo flower and in from seven to twelve days pass into the pupal stage which lasts from three to five days. The adult then emerges and in about five days begins to produce another generation. It usually requires from two to three weeks for the weevils to develop from egg to adult. A period of about forty days is required for a complete generation and usually only four or five generations are produced each season. According to Hunter (1917), "Males and females are produced in about equal numbers. The males feed upon the squares and bolls without moving until the food begins to deteriorate. The females refrain from depositing in squares visited by other females. This applies throughout most of the season, but late in

the fall, when all the fruit has become infested, several eggs may be placed in a single square or boll. As many as 15 larvae have been found in a boll. The squares are greatly preferred as food and as places for depositing eggs. As long as a large supply of squares is present, the bolls are not damaged to any serious extent. The bolls, therefore, have a fair chance to develop as long as squares are being formed."

FIG. 99.—Larvae of the Mexican boll weevil in the bolls of Egyptian cotton. (*U. S. Dept. Agr., States Relations Service*).

The weevil causes the destruction of a great many squares and the most conspicuous evidence of their presence is the flaring and falling of squares in great numbers.

Control.—Certain parasites are effective in reducing the attacks of the boll weevil, as they prey upon the immature stages of the insect. Many of the larvae and pupae are killed in the squares which fall to the ground and remain exposed to the sun. The loss from attacks of the boll weevil can be greatly reduced by the destruction of the places of hibernation and of the old cotton plants as soon as the crop is picked. The planting of early maturing varieties of cotton, liberal fertilizer applications to hasten maturity, and crop rotation are recommended. Arsenical poisons, especially calcium arsenate, have been used with good results in controlling the weevil.

Smith (1922) has worked out a method of boll weevil control for Florida conditions which consists in: (1) removing all squares from the cotton plants about June 5th and destroying them; and (2) following this

Fig. 100.—Fighting the boll weevil by the Florida method. (*Fla. Agr. Expt. Sta. Bul.* 165).

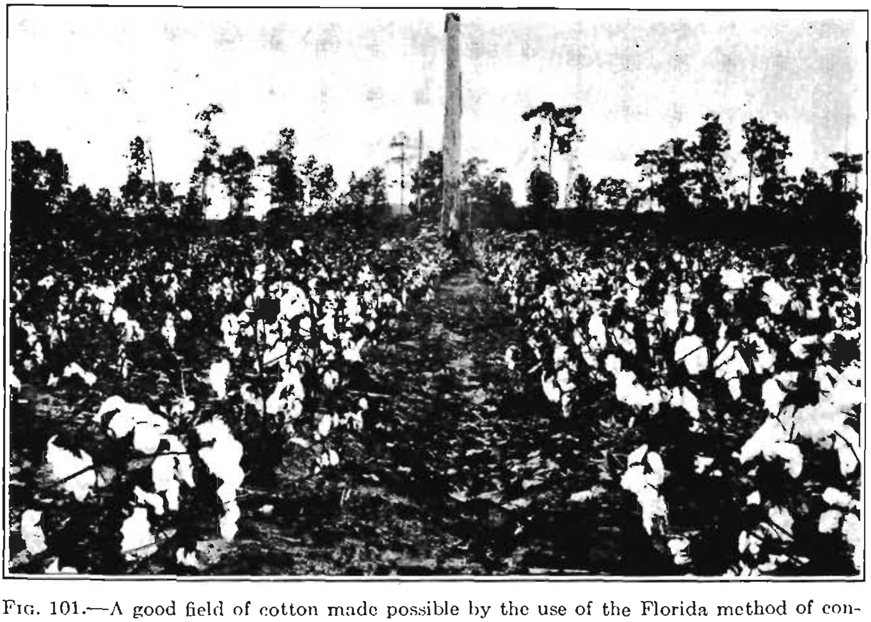

Fig. 101.—A good field of cotton made possible by the use of the Florida method of controlling the boll weevil. (*Fla. Agr. Expt. Sta. Bul.* 165).

removal at once with a thorough application of calcium arsenate or lead arsenate applied as a dust. However, it is not likely that this method will be efficacious in sections with shorter growing seasons.

SOME DISEASES

Cotton Wilt.—Cotton wilt or blackroot is caused by the fungus *Fusarium vasinfectum.* The disease often occurs with root knot. The wilt of cotton, according to Gilbert (1921), causes a larger loss than any other disease attacking the crop.

The fungus plugs the water ducts in the stems and thus brings about wilting and death of the affected plants. Since the dead roots of the diseased plants turn black, we have the name blackroot. When cotton plants wilt and die without apparent reason, wilt is to be suspected. When the stems of freshly wilted plants affected with this disease, are cut near the ground, they have a black or brown appearance. Wilt affected plants are considerably stunted and frequently the main stem remains shortened, while the lower branches may grow normally. The disease usually occurs first in irregular spots over the field. These spots increase in size from year to year, and the diseased plants begin to die early and continue to do so throughout the season. The disease occurs almost entirely on sandy or sandy loam soils, and is spread by the growth of the fungus through the soil or by any agency which will carry the spores from one place to another. The transfer may be effected by plows, cultivators, feet of men, drainage water and similar means.

Control.—The most effective methods of control are rotation of crops and the use of wilt resistant varieties of cotton. Recent experiments by Rast (1922) in Georgia indicate that potash fertilizers may be important in controlling wilt.

Root Knot.—Root knot of cotton is caused by minute eelworms or nematodes (*Heterodera radicicola*). The disease attacks a number of other plants in addition to cotton. It causes great loss to the cotton crop, ranking second only to wilt in its noxious effects. The nematodes enter the roots of the plants and cause irregular swellings to appear on the roots varying from tiny enlargements to knots an inch or more in diameter.

The disease is most serious on sandy soils, being seldom of much importance on the heavy soil types. The badly affected plants are stunted, the leaves and stems may have a yellowish green color, and, in dry weather, the plants often wilt in the middle of the day. The enlargements which occur on the roots may appear on the small as well as on the large roots. The young galls are almost white but later turn brown and decay. Galls cause stunting of the plants, through cutting off of the food and water supply.

The disease may be spread in many ways such as by plows, cultivators, feet of men and animals, use of infected manure, drainage water and similar agencies.

Control.—Bessey and Byars (1915) state that the most satisfactory method of controlling root knot is by the use of a two or three year rotation of immune crops, care being taken to kill all susceptible weeds and plants which may start to grow. Some of the crops which are immune or practically so are barley, Brabham and Iron cowpeas, corn, peanuts, rye, wheat and winter oats.

Anthracnose.—Anthracnose, also called boll rot or boll spot, is caused by the fungus *Glomerella gossypii.* The fungus attacks the bolls, seedlings, leaves and stems of the plants. On the boll the disease first appears as small water soaked areas which increase in size covering all or nearly all of the boll. The spots become black and later have reddish borders and pink centers. The lint from the affected bolls is usually stained pink and is frequently rotten and worthless. The seedlings when attacked often die before appearing above ground. During cold damp weather the fungus may cause a damping off of the seedlings at the surface of the ground, but usually the entire stem below the surface is dark colored and diseased. The attack on the leaves and stems is chiefly limited to weak or injured parts. The leaves sometimes have a yellowish color, wither, and die as if frosted. The seed leaves and leaf scars are especially susceptible to infection.

The disease may be disseminated by wind, rain, insects, animals, contamination in the cotton gin, diseased parts of the cotton plant and by seed. The latter method of dissemination is the most important.

Control.—In the control of the disease Barre (1912) of South Carolina recommends the use of disease-free seeds and rotation of crops. The seeds to be used for planting should be field selected from plants free of the disease. However, the organism does not remain alive in the seeds for longer than three years. The fungus does not remain alive in the field on dead stalks and bolls for much longer than twelve months. Therefore, leaving cotton off the land for one year will control the trouble if disease-free seeds are used. Some varieties of cotton are less susceptible to anthracnose than others.

CHAPTER XXXVII

TOBACCO (Nicotiana tabacum)

Although tobacco is chiefly used as a stimulant and the acreage is comparatively small, it is one of the great money crops of the United States. In 1919 it ranked seventh in value of the crops of the United States but occupied only one-half of 1 per cent of the total acreage in crops.

Over 80 per cent of the tobacco acreage is in five states: Kentucky, North Carolina, Virginia, Tennessee and Ohio. Smaller centers of production are located in South Carolina, northern Florida, southern

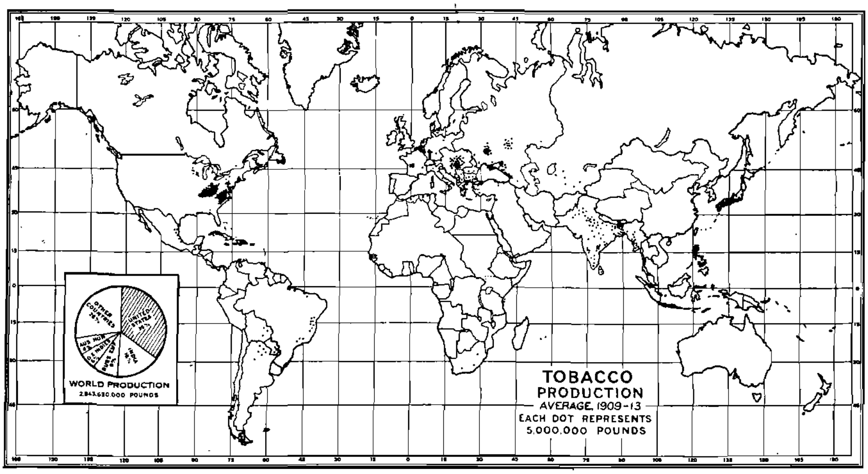

Fig. 102.—Tobacco may be grown successfully under a wide range of conditions of soil and climate, as shown by the fact that this crop is an important one in many parts of the world. The commercial value of the product, however, is influenced to an extraordinary degree by soil and climate so that the product of different countries varies greatly in market value. (*U. S. Dept. Agr. Yearbook*, 1922).

Maryland, southeastern Pennsylvania, the Connecticut Valley and Wisconsin. In sections where it is grown, it usually is the most important money crop.

World Production.—Figure 102 shows the world production of tobacco for the 5-year period, 1909 to 1913.

Production in the United States.—Figure 103 shows the acreage of tobacco for the United States in 1919.

The average annual yield for the United States as a whole for the 5-year period, 1910 to 1914, was 991,958,000 pounds, with an average

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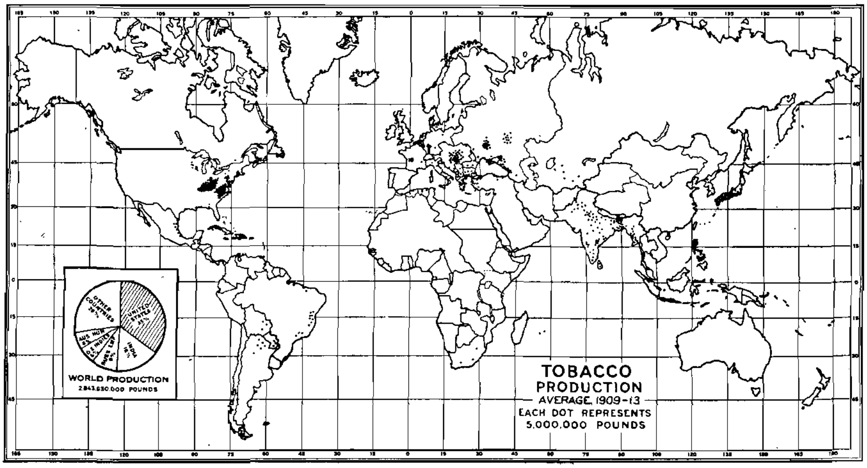

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The average annual yield for the United States as a whole for the 5-year period, 1910 to 1914, was 991,958,000 pounds, with an average

acre yield of 820.5 pounds; during the period, 1915 to 1919, the average annual production was 1,273,869,000 pounds and the average acre yield was 807.9 pounds.

Tobacco may be grown in every state in the United States, but it appears that certain soil types and climatic conditions are necessary for the highest quality and best flavor in the manufactured product. In 1919 the four states, Kentucky, North Carolina, Tennessee and Virginia, produced 1,001,072,817 pounds of tobacco, or 72.9 per cent of the entire crop.

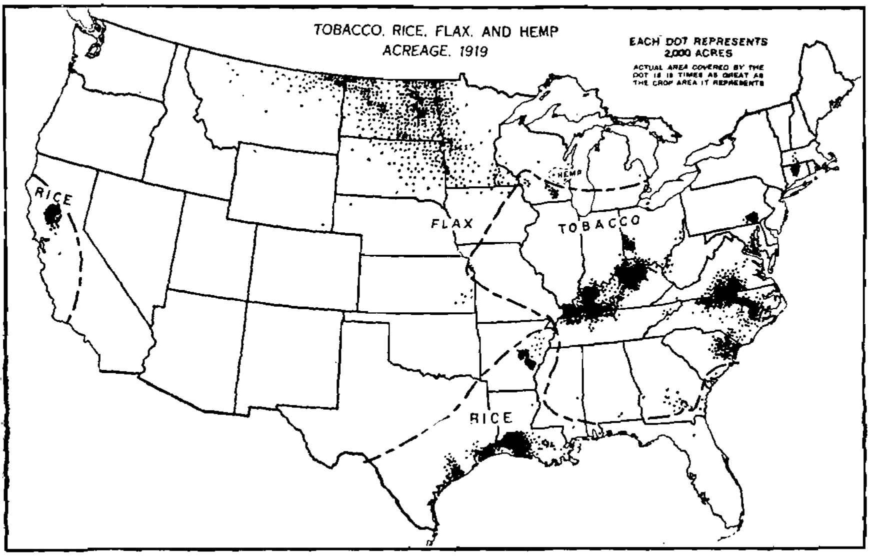

FIG. 103.—Nearly 90 per cent of the tobacco acreage is in six States—Kentucky, North Carolina, Virginia, Tennessee, South Carolina, and Ohio. But there are also important centers of production, especially of certain types, in southern Maryland, in Lancaster County, Pa., in the Connecticut Valley, and in southern Wisconsin. Tobacco is very sensitive to soil conditions, but these requirements vary with the different types.

Rice production is now largely confined to the coastal prairies of Louisiana and Texas, the prairie district of eastern Arkansas, and the flat valley of the Sacramento in California, all areas of heavy subsoils which hold the irrigation water.

Flax is grown in the spring wheat and northern Great Plains areas. Nearly half of the hemp is raised in Wisconsin. (*U. S. Dept. Agr. Yearbook*, 1921).

Historical.—Tobacco is one of the important native American crop plants. It was cultivated by the Indians at the time of the discovery of America, and according to Carrier (1923) was generally grown over both North and South America and the West Indies. The name "tobacco" is derived from the Indian word *tabaco*, which was the name of a pipe used by the Indians for smoking the leaves of the plant. Tobacco was taken to Europe by the Spaniards at an early date. The botanical name *Nicotiana* and the name of the active principle of the plant, nicotine, are derived from the name of Jean Nicot, a French Ambassador to

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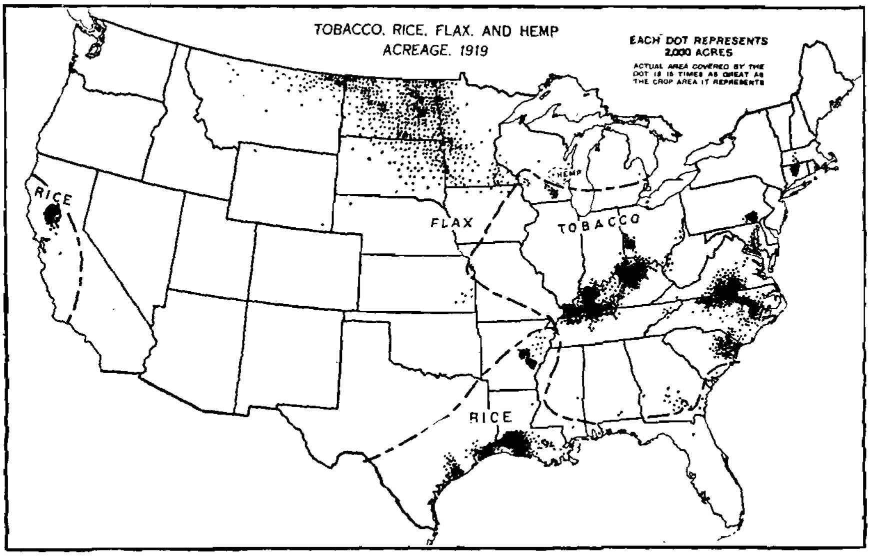

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Portugal, who in about 1560 introduced tobacco into France. Sir Walter Raleigh is usually given credit for having introduced tobacco into England.

The use of tobacco soon became popular in Europe and it was credited with many virtues, such as allaying hunger, dispelling fatigue and curing various diseases. The growth of tobacco was closely identified with the development of the early colonies, especially in Virginia and Maryland. It is doubtful whether these colonists could have existed and developed as they did without tobacco, as it was one of the few things produced by the colonist which could be exported and exchanged for many necessary articles which came from the Mother Country. It early became a medium of exchange in the colonies and was used in lieu of money. Whitney and Floyd (1899) state that it was made legal tender in Maryland in 1732 at the rate of 1 penny per pound for all debts, including custom-house dues, and for the salaries of state officers and ministers of the gospel.

According to Garner (1910) commercial tobacco culture began in Virginia in 1612. The industry promptly spread to Maryland; and when Kentucky was settled, tobacco at once became the principal crop in that territory. From Kentucky it was carried into Tennessee and Missouri. It was introduced from Virginia into North Carolina about 1850 and in 1890 became commercially important in South Carolina.

The New England colonists at an early date began the culture of the crop but tobacco did not become of much commercial importance there until about the middle of the last century, when the value of the tobacco produced in that section for the manufacture of cigars was recognized. From New England the growing of the cigar types was extended into Pennsylvania, New York, Ohio and Wisconsin. About 1890 the production of cigar tobacco from Cuban and Sumatra seed began to assume importance in Florida and southern Georgia.

Classification.—Garner (1914) recognizes three general classes of tobacco: (1) cigar tobacco; (2) export tobacco; and (3) manufacturing tobacco. This classification is based on the purposes for which the plant is grown. These classes are further divided into types according to characteristics and appropriate use. In the case of cigar tobacco, there are three principal types corresponding to the three parts of the cigar, namely, wrapper leaf, binder leaf and filler leaf. The types recognized in manufacturing and export tobacco are Virginia sun-cured, white Burley, flue-cured and dark fire-cured. These various types are produced on certain special types of soil and according to definite methods of growing, curing and handling of the crop.

Distribution of Types.—*Cigar Types.*—The Connecticut Valley area and certain localities in Georgia and Florida are the principal *wrapper leaf* sections, while Wisconsin, New York and Pennsylvania

produce principally a *binder leaf* type. The *filler leaf* type is produced mainly in Lancaster County, Pennsylvania; the Miami Valley, Ohio; and the Onondaga district of New York. There are also restricted areas in Georgia and Florida which produce a desirable filler leaf.

Export and Manufacturing Types.—The *flue-cured* type is produced chiefly in southern Virginia, North Carolina and South Carolina. In recent years this type has been introduced as a substitute for cotton in many of the boll weevil sections of the other southern states.

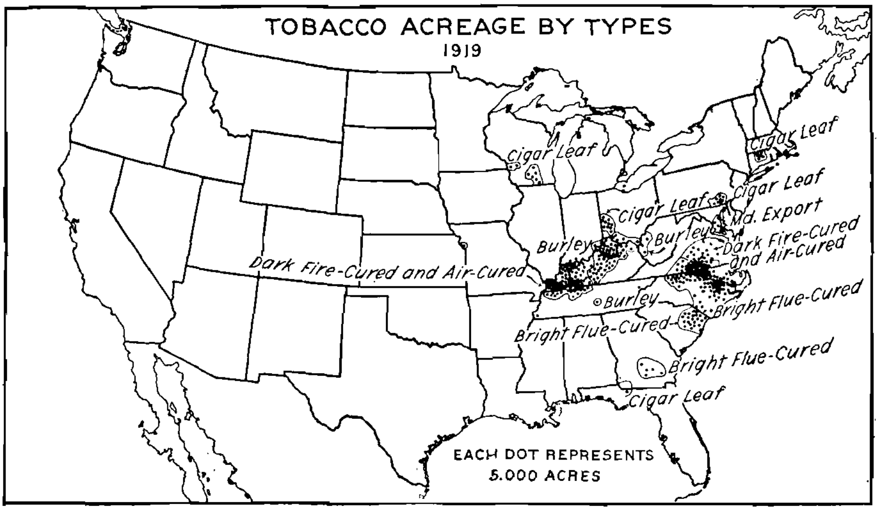

FIG. 104.—Each distinctive type of tobacco has its special requirements as to soil and climate and the present localization of production of the various types is the result of a long process of evolution and specialization. (*U. S. Dept. Agr. Yearbook*, 1922).

The *fire-cured export* type of tobacco is grown almost exclusively in western Kentucky, Tennessee and central Virginia, while the *Virginia sun-cured type* is grown in a rather restricted area in north central Virginia. The *white Burley* type is produced in north central Kentucky, southern Ohio, southwestern West Virginia and southeastern Indiana.

Varieties.—There are many varieties and strains of tobacco, and often strains which have the same varietal name are very dissimilar in type. This lack of similarity is due to the fact that only a few tobacco seed plants are required to produce enough seeds to plant several acres, and farmers often differ in their opinion as to what constitutes a good seed plant. Each farmer selects for seed those plants which most nearly meet his ideas of the best type for his conditions and in a very short time the type may be considerably differentiated. No attempt will be made to discuss the many strains and only the more important varieties will be mentioned. The varieties here mentioned are largely taken from Garner (1914).

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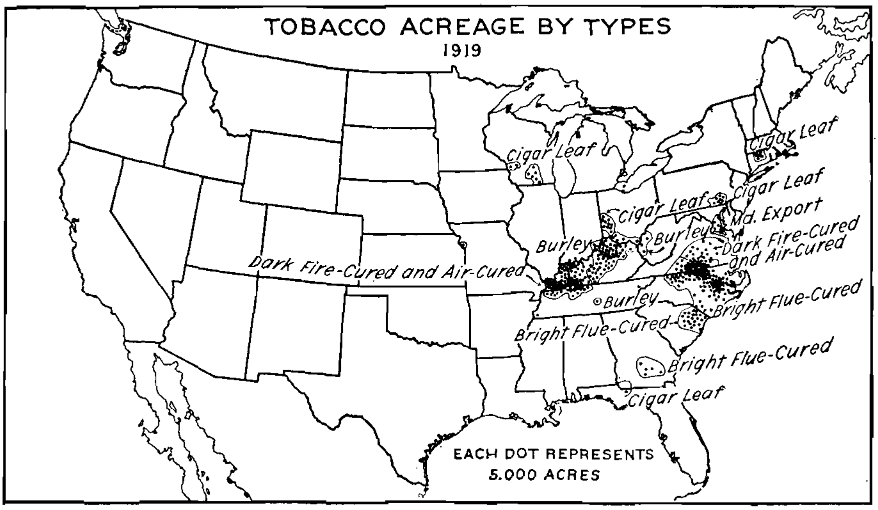

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Cigar Varieties.—There are three important groups of varieties used in growing cigar tobaccos in the United States. These are: (1) the Broadleaf or Seedleaf group; (2) the Havana seed group; and (3) the Cuban group. The Connecticut Broadleaf is typical of the Broadleaf group. Acclimated strains of this variety have been developed and are grown in all the northern cigar leaf states, and in each case these strains are given the name of the state in which they are grown. Thus, we have Pennsylvania Broadleaf, Ohio Broadleaf, and so on for the other states growing this variety. The name "Havana Seed" is usually applied to this variety as grown in any of the northern states, but the state name is often prefixed as in the case of the Broadleaf group. Closely related to this group are the so-called Spanish varieties, the most important of which are Zimmer Spanish and Comstock Spanish. These two last mentioned varieties are grown chiefly in Ohio and Wisconsin. Little Dutch, a narrow-leafed strain, which is supposed to have been introduced from Germany, is of some local importance in parts of Ohio.

The Cuban group is composed of strains and selections obtained from seed imported from Cuba. This group is grown for filler leaf mainly in the southern cigar tobacco districts.

Export and Manufacturing Varieties.—The principal varieties used in the production of export and manufacturing tobacco may be grouped under these heads, namely, (1) Burley group; (2) Maryland group; and (3) flue-cured and fire-cured.

White Burley is the most important variety in the Burley group. Important subvarieties are stand-up Burley and twist-bud Burley. The Maryland is the most important variety of the Maryland group, with Broadleaf and Narrowleaf Maryland as subvarieties.

In the flue-cured and fire-cured export and manufacturing group there are many varieties, most of which have been developed from the Orinoco and Pryor varieties. For the production of bright or flue-cured tobaccos, Warne, Adcock, Little Orinoco, Gooch, Flanagan and Gold Leaf are important kinds. Narrow-leaf Orinoco, White Stem Orinoco and Lizard Tail are popular for the production of Virginia sun-cured tobaccos. Lizard Tail, Yellow Pryor, White Pryor, Yellow Mammoth and One Sucker are important in the production of dark fire-cured tobaccos.

Botanical.—Tobacco (*Nicotiana tabacum* Linn.) belongs to the order *Solanaceae*, the genus *Nicotiana* and the species *tabacum*. The plant is a rank growing annual with a rather small root development as compared with the size of the plant. It has a central tap root from which numerous rather short lateral roots extend. Its roots are in large measure restricted to an area the radius of which is seldom more than 18 inches. It has a simple cylindrical stem that attains a height of from 4 to 8 feet when not topped. The leaves are alternate and often attain a size of 1 foot or more in width and 3 to 4 feet in length. All of the green parts of the plant

are covered with a soft, downy, glandular pubescence which makes the surface sticky. The stem terminates in a panicle of showy, pink or rose-colored flowers, each with a long corolla tube. The plant is normally self-fertilized but cross-fertilization is easily effected by visits of insects carrying pollen from other plants. The seeds are borne in large capsules and are produced in great numbers; a single well-developed plant often producing as many as 1,000,000 seeds.

Uses.—Tobacco is used chiefly for chewing, smoking and snuff. Low-grade leaf and by-products are used in the production of insecticides, disinfectants and other nicotine products. The stalks, stems and some by-products of the nicotine industries are used for fertilizers.

Culture

Plant Bed.—Tobacco plants are started in beds seeded 6 to 12 weeks before time to set the plants in the field. In the cigar tobacco sections of the North, the young plants are started in a cold frame or hotbed; but in Kentucky, Virginia and the states farther south, a sunny exposure is chosen, either in recently cleared woodland or in the open field. In bluegrass sections a common practice is to turn a bluegrass sod in the early fall so that the sod will have time to decay by the following spring. The sod is then worked up and raked until a very fine seedbed has been made; the seeds are then sown.

When plant beds are made on recently cleared woodland, the usual practice is to pick a place rich in organic matter and work it up with a mattock or some horse-drawn implement which does not bring any of the subsoil to the top. The bed is then raked until it is in a fine condition.

Burning and Steaming.—Since weeds and diseases are very objectionable in plant beds, the beds are usually burned or steamed before the ground is prepared for seeding. When the beds are burned, either wood or brush is piled on them and burned until the soil is thoroughly heated to a depth of 2 or 3 inches.

In the steam treatment, an engine and a metal box are necessary. The box is inverted over a part of the bed with the edges forced well into the soil so that the steam cannot escape. Then the steam is forced into the box until the soil is heated to temperature of 175° F. to a depth of 4 inches. The temperature is maintained for about an hour and the pan is then moved to another area where the process is repeated. Where suitable steam engines are available, steaming is preferable to burning as it is more effective in killing both weeds and disease organisms which may be in the soil.

Fertilizers.—To produce good plants the soil should be very rich in available plant nutrients. It is, therefore, usually advisable to fertilize the beds. Well-rotted farmyard manure applied at the rate of 20 tons

to the acre gives good results. Hog manure is splendid for the purpose as it does not carry many weed seeds. However, if the beds are steamed after manuring, any well-rotted manure may be used. Even when the beds have had a good application of farmyard manure, the application of commercial fertilizer is advisable. The fertilizer most commonly used on the plant beds is of the same analysis as that used later on the tobacco fields. This fertilizer is applied at the rate of 50 to 100 pounds to each 100 square yards of plant bed. When suitable farmyard manure is not available, if there is a good supply of organic matter in the soil, very good plants can be grown by the use of commercial fertilizers alone.

Seeding.—The seed is sown on the bed at rates varying from a level teaspoonful to 100 square feet, to the same amount for 300 square feet. Probably the best rate of seeding is an even teaspoonful of dry seed to 100 square feet of bed area. In order to get an even distribution of the seed it is mixed with fertilizer or some other light-colored material and the bed is gone over several times until the distribution of the filler material indicates that the entire surface has been seeded.

The seed should be raked in very lightly and the bed then run over with a light roller. If a roller is not available, the soil may be packed with a short piece of plank with a handle attached.

Care.—After the seed has been sown, the bed should be covered either with cheesecloth or with glass. In colder sections glass is preferable, but in the South the cheesecloth covering is used almost exclusively.

The beds should be kept moist enough to insure rapid growth, and weeds should be picked out by hand. When the plants have reached the height of 6 inches, they are ready for setting in the field. The covers should be removed from the beds several days before the plants are to be set in the field, so that they may be toughened by exposure.

Preparing the Field.—The land should be plowed either during the winter or early in the spring. Care is required in the preparation of the soil and it should be in good tilth when the plants are set.

Fertilizer for Tobacco.—Special attention must be given to the matter of fertilizing the crop. For all types of tobacco except the flue-cured or bright tobacco, heavy applications of barnyard manure may be plowed into the soil. In the cigar tobacco districts the commercial fertilizers are commonly broadcasted, after the land has been thoroughly prepared. However, in the export and manufacturing tobacco sections, after the commercial fetilizers have been drilled in the furrow and thoroughly mixed with the soil, a slight ridge is thrown over the furrow and the plants are set on this ridge. Garner (1914) recommends a ton to the acre of commercial fertilizer analyzing 5 per cent nitrogen, 5 per cent phosphoric acid and 6 per cent potash for cigar tobaccos on land which has been well manured; and when no manure is applied, he recommends the same amount of fertilizer carrying 6 per cent nitrogen, 5 per cent phosphoric acid and

6 per cent potash. For bright or flue-cured tobacco, Hart (1920) in Virginia advises the use of 1,000 to 1,400 pounds to the acre of a fertilizer analyzing 3 per cent nitrogen, 8 per cent phosphoric acid and 3 per cent potash. He advises against the use of heavy applications of farmyard manure and legumes before bright tobacco, as these materials have a tendency to cause the production of a leaf of poor quality which does not cure bright.

FIG. 105.—Tobacco responds well to the use of fertilizer. A heavily fertilized field of bright tobacco.

The dark fire-cured types of tobacco are commonly grown on the most productive lands available in the section and farmyard manure is used when it can be obtained. The amount of commercial fertilizer used varies from 200 to 2,000 pounds to the acre and usually contains 3 per cent nitrogen, 8 per cent phosphoric acid and 3 per cent potash.

Transplanting and Cultivating.—Tobacco plants are usually set in rows 3 to 3½ feet apart. The distance between the plants in the row varies from 14 to 30 inches for cigar tobaccos and from 30 to 36 inches for the manufacturing and export types.

The plants may be set out on the level surface of the land, but they are usually set on slight ridges. The plants may be set by hand but transplanting machines are used in some sections. Where hand planting is practiced, the plants should not be transplanted except when there is an abundance of moisture in the soil. The land must therefore be prepared several days ahead of planting time so that the plants may be set as soon after a rain as possible. The best time for setting plants is as soon as possible after the last killing frost date of the section. Early-planted tobacco cures better than late-planted, although the plants may be set as late as 90 days before the date of the first killing frost in the fall.

Cultivation should begin as soon as the plants start to grow and should be repeated often enough to kill the weeds and to keep the soil loose on top, as long as the size of the plants will permit. The first cultivation may be deep; afterwards frequent shallow cultivations are more desirable. It is often advisable to work the soil around the plants with a hoe after the first cultivation; but if subsequent cultivations are timely and thorough, additional hoeing may not be necessary.

Topping and Suckering.—Topping, which means breaking off the top of the plant, is practiced to stimulate development of the leaves. No definite rule can be given for topping as this depends upon many factors, such as type of tobacco, productivity of the soil, date of planting and rainfall. In the production of cigar tobaccos, 16 to 20 leaves are often left to each plant, while with the export and manufacturing types 8 to 12 leaves are usually left. The aim in topping is to leave only as many leaves on the plant as can be brought to the fullest development. The suckers or axillary buds come out at the axils of the leaves on all plants which have been topped. These suckers should be removed as often as they appear and should not be allowed to grow more than 3 inches in length.

Harvesting.—There are two general methods of harvesting tobacco: (1) picking the leaves from the stem as they ripen and (2) cutting the stalks with the leaves intact. Both of these methods are used in harvesting cigar and flue-cured tobaccos, but the practice of cutting the stalk is used almost exclusively in the harvesting of dark fire-cured tobacco. After the plants are cut, they are allowed to wilt so that the leaves will not break so easily; afterwards they are placed in the curing barns. Both the leaves and plants are hung on sticks or laths before being placed in the barns and the leaves are tied to the sticks with cotton strings. When the whole plant is cut, the stem may be split for a short distance at the top and the plant placed astride the stick; or the stalk may be pierced near its base with a removable "spearhead" placed on the end of the lath, and the stalk thus hung on the lath. From five to seven plants are placed on each lath or stick according to the size of the plants.

Curing.—The three common methods of curing tobaccos are: (1) air curing; (2) open fire curing; and (3) flue curing. In the air-curing process the tobacco is hung on tiers of poles in barns provided with ventilators which admit the air freely. In dry weather the ventilators are kept open day and night, but on very damp nights they are closed. In damp weather it may be necessary to keep the ventilators closed day and night. The curing process is slow and may take several weeks if weather is unfavorable.

In the dark tobacco districts the tobacco is either taken to the barn as soon as it has wilted or hung on scaffolds in the field to yellow to some extent; afterwards it is placed in the barn. After yellowing has gone to

the proper point, open fires are built on the ground directly under the tobacco. Slow fires are kept up for the first few days and are then gradually increased until curing is completed. This process often takes 10 days or more. In some cases the fires are not kept up constantly but are built at irregular intervals according to the grower's ideas concerning the need of fire.

Bright tobacco is cured in a much shorter time than either of the other types. The barns have close walls and are provided with ventilators

FIG. 106.—A field of bright tobacco showing curing barns in the background.

at the top. Furnaces or fire boxes are built in one side and flues lead from these across the house and then back and pass out through the wall a few feet higher than the level at which they left the furnace. The barn is filled with tobacco as quickly as possible. A moderate fire is then started and maintained until the leaf is thoroughly yellowed. The temperature is then gradually raised as the curing progresses and due attention is given to ventilation so that proper moisture conditions will be maintained No fixed rule can be given either for regulating the temperature or for adjusting the ventilators, as these operations vary with each curing of tobacco and can be learned only by experience. The temperature is finally raised to 175 or 200° F. and maintained until all the stems are dry. The whole process seldom takes more than three days.

Stripping, Sorting and Tying.—After tobacco is cured, it is allowed to hang until the leaves become pliable owing to the absorption of moisture. The tobacco may then be handled without breaking and may be taken down and prepared for market. Tobacco becomes pliable only in damp

weather and becomes dry and brittle again when the weather is dry and cool. In order to keep tobacco pliable, it may be placed in bulk and covered to keep it from drying. Some growers have ordering rooms in which tobacco may be hung and brought into pliable conditions by steam or other methods of supplying moisture to the surrounding air.

The stripping process consists in removing the leaves from the stem. The leaves are then sorted according to quality and tied into "hands" or bundles. A hand is a bunch of several leaves which are tied together at the butts with another leaf. The tobacco is then ready for market and may be sold at the grower's convenience.

SOME INSECT PESTS

Tobacco Flea Beetle.—The tobacco flea beetle (*Epitrix parvula*) is a small, oval, reddish-brown insect about one-twentieth of an inch long. The eggs, which in about one month transform into pupae and then into adult beetles, are laid in the soil, and the larvae feed upon the roots of the susceptible plants. The life cycle requires about one month, and several generations are produced each season. The adult beetle lives overwinter in rubbish which often accumulates in fence corners and elsewhere.

The beetle attacks not only tobacco but egg plants, tomatoes, potatoes and so forth. The insects damage the leaves of the tobacco plant by eating small holes in the upper or under surface or through the leaves. This damage of course affects the selling quality of the crop and in addition makes easier the entrance of certain diseases. The plants are attacked both in plant beds and in the field.

Control.—Plant beds properly covered will reduce the attacks of the beetles. By dusting or spraying the plants with Paris green or arsenate of lead, as for hornworms, one can lessen the injury from the attacks. The plants may be dipped in arsenate of lead solution (1 pound of paste or ½ pound of powder to 10 gallons of water) just before setting.

Tobacco Hornworms.—The tobacco hornworms (*Phlegethontius sexta* (Southern) and *P. quinquemaculata* (Northern) in the adult forms are moths, one being more common in the North and the other in the South. The Southern is darker, with brighter orange spots on the abdomen, while on the wings the white lines are less distinct.

The pupae overwinter several inches below the surface of the ground and the adult moths emerge in May and June. On the under surface of the leaves the females deposit eggs from which the larvae emerge in from 4 to 8 days. The larvae, which are very ravenous and devour leaves in large quantities, become full grown in about 3 weeks after moulting four times. They are 3 to 4 inches long and dark green in color with white stripes on the side of the body. The stripes of the

Northern species are V-shaped and those of the Southern species are single, oblique bands. A short horn is attached to the tip of the abdomen; in the Northern species the horn is black while in the Southern species it is red. From the presence of the horn the insect is sometimes called "hornworm." The larvae enter the ground and pupate for about 3 weeks, when the adults emerge, the entire life cycle requiring about 6 to 8 weeks. In the South two generations occur each season, while in the North only one is produced.

Control.—The insect is often controlled by picking off the larvae as they appear. The plants may be dusted or sprayed with Paris green or arsenate of lead. If the spray is used, it may be mixed as follows: Paris green ¼ pound or arsenate of lead (powder ½ pound or paste 1 pound) to 10 gallons of water. Morgan (1917) recommends dusting in preference to spraying and the use of arsenate of lead rather than Paris green. The recommendations are as follows:

Paris green, although an effective insecticide, frequently burns tobacco very severely and may reduce the value of the crop by as much as 50 per cent in exceptional cases.

Arsenate of lead never seriously injures tobacco even under the most unfavorable conditions.

A dosage of Paris green large enough to be effective against hornworms cannot be applied without grave danger of burning tobacco.

Paris green, which is applied in dust form without a carrier, is used at the rate of from 1 to 2 pounds per acre.

Arsenate of lead is safe and effective during rainy weather, whereas Paris green is dangerous and ineffective.

It is recommended that arsenate of lead be used against the tobacco hornworms and that it be applied as a dust or powder.

The dosage of arsenate of lead in powdered form varies from 3½ to 5 pounds per acre. If applied as a spray, from 3 to 4 pounds in 100 gallons of water.

To apply arsenate of lead in powdered form, without a carrier, use a dust gun having a fan diameter of at least 10 inches and a special device for preventing clogging of the delivery pipe. If a gun with such a device is not used, it will be necessary to mix the arsenate of lead thoroughly with equal parts of *dry* wood ashes.

Apply arsenate of lead when there is no breeze and when dew is on the plants.

Use only such brands of arsenate of lead as are guaranteed to contain at least 30 *per cent of arsenic oxid, of which not more than* 1 *per cent is free, or water-soluble.*

SOME DISEASES

Root Rot.—Root rot is of considerable importance because of the serious losses which sometimes ensue from the attacks of this disease. The root rot disease is caused by the fungus *Thielavia basicola,* which lives as a parasite on the roots of the plant.

The disease may be first noticed in plant beds. The diseased plants are small and stunted, while the healthy ones are vigorous and strong. The roots of the affected plants are small in size and few in number. They are also in the process of decay, which begins at the tips. The plants frequently have a sickly yellow color and may not reach sufficient size to transplant. Often the plants are set in the field and new roots form. According to Johnson and Milton (1919) the growth which the diseased plants make in the field is controlled largely by temperature. If the season is cool (60 to 75° F.), the plants will remain for two or three weeks without any apparent growth and they will become yellow and die. In warm seasons (80 to 100° F.) the diseased plants may partially or wholly revive. The characteristic symptom of the disease in the field is a dwarfing of the plants resulting from decay of the root system.

The fungus lives from year to year in the soil where it can maintain itself, subsisting on decaying plant matter. Land badly infested is said to be "tobacco sick," a condition which is commonly believed to be due to depletion of available plant nutrients. The disease is spread by transfer of "sick" soil on the feet of animals, on implements, in drainage water or by setting affected plants in disease-free soils. In addition to tobacco, the fungus attacks other plants such as peanuts, soybeans, bur clover and cowpeas.

Control.—The losses from the disease may be greatly reduced by rotation of crops, by seedbed disinfection and by the use of disease-resistant strains of tobacco. Considerable progress has been made in the development of strains of white Burley tobacco resistant to root rot.

Blackfire and Wildfire.—Blackfire or angular leaf spot, and wildfire are sometimes considered the same disease but according to Fromme and Wingard (1922) they are distinct. Blackfire is a bacterial disease of tobacco caused by the pathogene (*Bacterium angulatum*). Wildfire is a disease caused by a bacterium (*Bacterium tabacum*). These diseases attack the plants both in the field and in the plant bed.

The evidence of *blackfire* is shown most readily in the plant bed when the plants have reached the transplanting stage. The most vigorous and healthy plants are usually most affected. The presence of the disease is shown by the appearance on the leaves of spots which are very small, angular in shape, black or dark brown in color, and surrounded by a narrow, clean border. The surrounding border is characteristic and makes a positive diagnosis possible. The spots on the seedlings remain small and usually appear first near the leaf margin close to the tip. The spots on the leaves in the field are much like the seedling spots in the early stages. These spots, however, become much larger when mature, and vary from tan to dark brown in color. There is no prominent halo as in wildfire, but the tissue around the spots is usually yellowish.

Wildfire occurs in the plant bed as does blackfire. The leaves of the seedlings are affected as evidenced by spots which are rounded in shape with a small brown center surrounded by a broad pale green or yellow halo. The field leaf spot is very similar in appearance to the seedling leaf spot, but the halo in the former becomes less conspicuous with age.

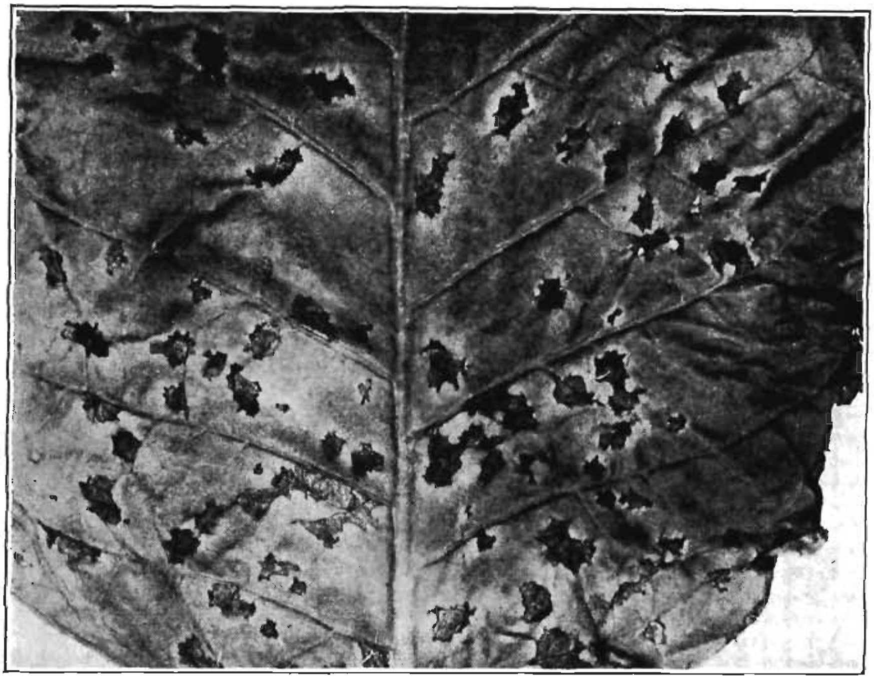

FIG. 107.—Blackfire or angular leaf spot infection of tobacco. Compare with Fig. 108. (*Va. Agr. Expt. Sta. Tech. Bul.* 25).

Both blackfire and wildfire attack the flowers and seed pods as well as the leaves. The lobes of the calyx seem to be especially susceptible to infection; and when diseased, they become blackened and recurved.

Sources of Infection.—The chief source of infestation of land with blackfire and wildfire is diseased plants. Therefore, the efforts to control these diseases should be directed toward the plant bed in hope of producing disease-free plants. However, there is some damage from field infection from the organisms overwintering in the soil or from the use of manure which is infested. Infection seems to become most easily effective in the following ways: (1) the use of contaminated seeds from infected pods; (2) the use of canvas that has been used on infested beds in previous years; (3) the use of the same plant bed in successive years or the location of the bed in close proximity to old tobacco fields; (4) the application of manure and other material containing refuse from a diseased tobacco

crop; (5) the transfer of infection from an infested bed to a clean one by man. The first two sources of infection seem to be the most important.

In the field rainfall is considered a potent factor in influencing the spread and development of the diseases. The water aids in the transference of the organisms and in the promoting of a vigorous succulent growth of the plants, which increases their susceptibility to attack. It also seems that a system of fertilizing or topping which promotes vigorous growth of the crops, other things being equal, also favors infection.

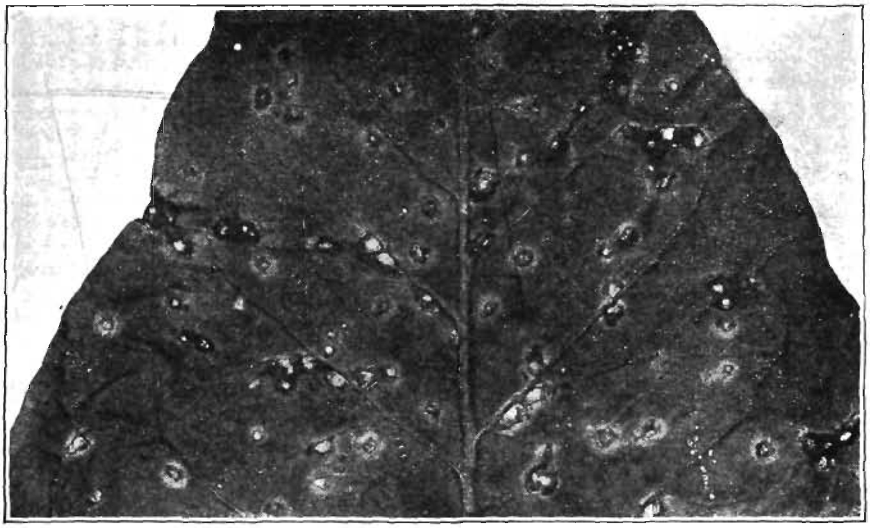

FIG. 108.—Wildfire infection of tobacco. Note the regular outline of the spots and the surrounding halos. Compare with Fig. 107. (*Va. Agr. Expt. Sta. Tech. Bul.* 25).

Control.—In the control of these diseases Fromme and Wingard (1922) recommended seed selection, seed disinfection, plant bed sanitation and field sanitation.

As far as possible seeds should be selected from pods which show no infection. The selected seeds may be effectively treated by soaking 15 minutes in a 1 to 1,000 solution of corrosive sublimate (1 part of corrosive sublimate or mercuric chloride in 1,000 part of water) and then by rinsing, drying and storing to prevent recontamination.

The plant bed should be made each year on new ground removed from fields which have recently grown tobacco. Poles, boards or canvas from the old plant beds should be discarded. However, the old canvas may be used if thoroughly disinfected by boiling. If tobacco is to be grown two years in succession on the same land, the stubble of the first crop should be turned under immediately after removing the crop. Materials which may be infected should not be applied to the land, and the crop should not be worked while the leaves are wet.

CHAPTER XXXVIII

POTATOES (Solanum tuberosum)

The potato is grown in practically every county in the United States. However, the crop does best in regions of relatively cool, uniform temperature with moderate rainfall. The soils most desirable are those which are friable, well drained and comparatively high in humus. As compared with other crops, the potato crop, in 1919, ranked ninth in acreage and sixth in value in the United States.

World Production.—The total yield and acreage of potatoes for the world is shown in Fig. 109.

Average Acre Yields.—The average acre yield for the 10-year period, 1910 to 1919, in the United States was 95.3 bushels; in Russia, 107.9 bushels; in Germany, 187.9 bushels; in Austria, 123.2 bushels; in Hungary, 122.2 bushels; in France, 108 bushels; and in the United Kingdom, 217.1 bushels.

Production in the United States.—Figure 110 shows the acreage of potatoes for the United States in 1919.

The average annual yield for the United States as a whole for the 5-year period, 1910 to 1914, was 360,772,000 bushels, with an average acre yield of 97.9 bushels; during the period, 1915 to 1919, the average annual production was 364,702,000 bushels and the average acre yield was 92.9 bushels.

In 1920 the six states, New York, Michigan, Wisconsin, Minnesota, Pennsylvania and Maine produced 191,756,000 bushels of potatoes, or 47.5 per cent of the entire crop.

Historical.—Scientists are agreed that the potato is indigenous to South America and that it probably originated in the central Andean region. However, one group of scientists claims Chile as its original home, while another group are inclined to regard Peru as the region from which it came. De Candolle (1886, page 53) states that the potato is wild in Chile in a form which is still seen in our cultivated plants and it is doubtful whether it is native to Peru. Carrier (1923, page 81), on the other hand, says: "They were not natives of Ireland as the common name might indicate but of Peru." The first known reference to the potato in literature is found in Cieca's "Chronicles of Peru," published in 1553, in which volume it is several times mentioned as a common source of food in Peru.

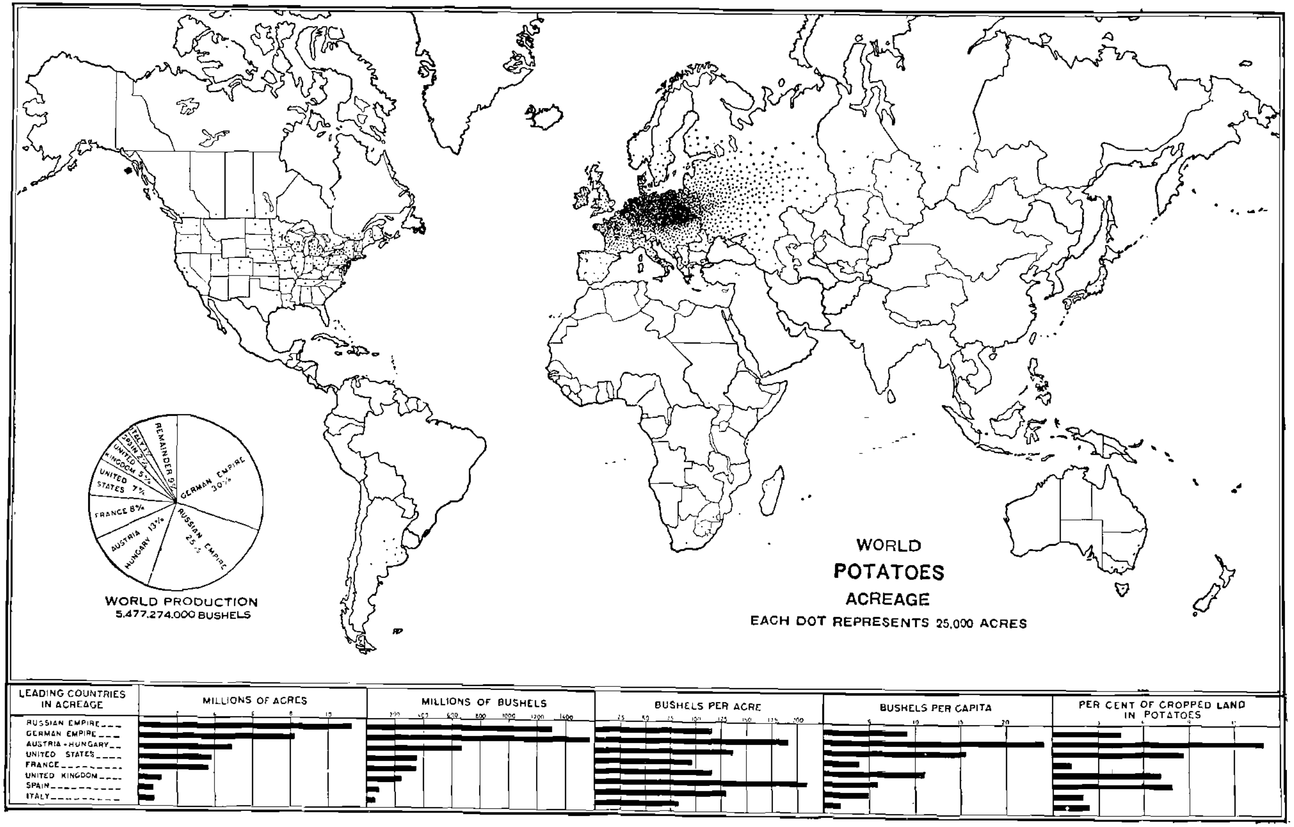

Fig. 109.—World acreage in potatoes (average 1911–13). Over 90 per cent of the potato crop of the world is grown in Europe. (*Finch and Baker*, 1917).

According to Carrier (1923, page 81) potatoes were probably brought to England about 1586 by Sir Francis Drake who obtained them on an expedition to the West Indies. The same author is of the opinion that the first plantings of potatoes in Ireland were made by Thomas Hariot, who was included in the second Raleigh expedition to Roanoke Island and in 1586 was sent to manage Raleigh's estate in Ireland.

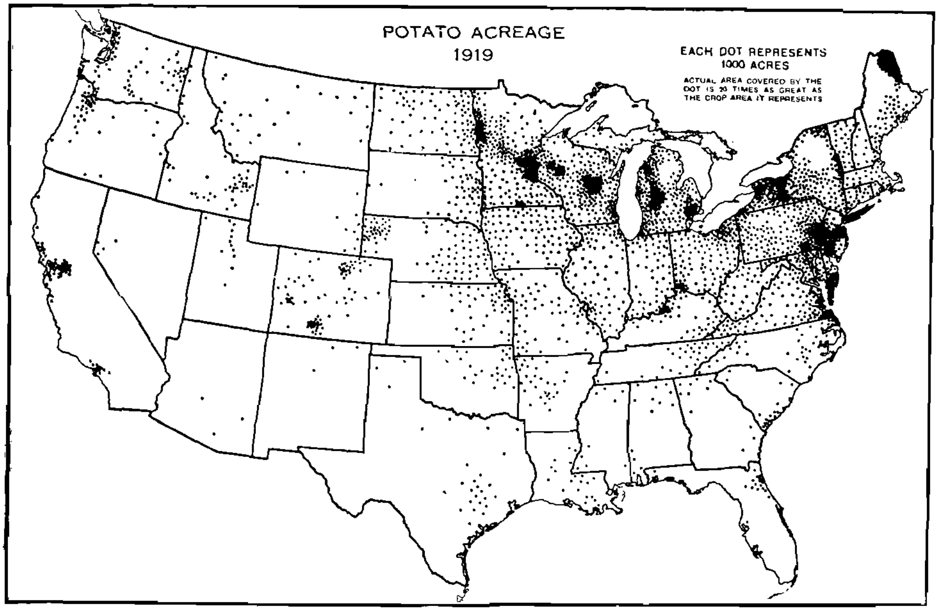

Fig. 110.—The regions of heaviest potato production lie to the north of the corn belt. This is due partly to the fact that the quality and yield of potatoes are better in regions of cool climate, and partly to the fact that corn, which requires labor at the same time, is very productive and gives a greater return. Many of the large centers of potato production are in regions of sandy or loamy soils—Aroostook County (Me.), Long Island, New Jersey, eastern Virginia, western Michigan, central Wisconsin and Anoka County (Minn.). Many of the minor centers of production are located near large cities, since potatoes are a bulky crop, expensive to transport, and can be sold at a profit by local gardeners and farmers in competition with the crop from the large production centers. (*U. S. Dept. Agr. Yearbook*, 1921).

The potato did not at first become popular in Europe nor was it used extensively as a food by the early colonists in America. It was brought into prominence by a shortage of other food crops in Ireland and was reintroduced from Ireland to the American colonies under the name "Irish" potato.

The culture of potatoes in the English colonies of America, as a staple crop, seems to have taken place between 1705 and 1749. During that period a large number of the Irish came to America, and it is likely that they continued the culture of this crop which had become an important food crop in Ireland.

Classification.—Potatoes have been classified into eleven groups by Stuart (1915). Later another group was added. The distinctions used in classification are shape, color of tubers, color of sprouts and color of flowers.

In *shape* the tubers may be round, oblong and long. They may be flattened or round, broad or narrow, spindle-shaped or tapering at one end, or uniform throughout the entire length.

The *color of skin* may be white, creamy white, flesh-colored, pink, rose, red and bluish, mottled and russet brown.

The tubers may also be smooth, russet, or marked with russet dots and varying degrees of russeting. Some varieties are glistening and smooth; others are dull.

The *sprout colors* can best be determined by studying potatoes which have been sprouted in the dark. The base of the sprouts may be either white or colored, as also may the scales or leaflets at the tips of the sprouts.

The ordinary colors are white, creamy white, pink, rose, rose-lilac, magenta, lilac, violet and deep violet.

The *flower colors* are white, rose, rose-lilac, rose-purple and purple and violet.

Groups.—There are twelve groups of potatoes: Cobbler, Triumph, Early Michigan, Rose, Early Ohio, Hebron, Burbank, Green Mountain, Rural, Pearl, Peachblow and Up-to-date.

Varieties.—There are 400 to 500, and perhaps a larger number, of varieties of potatoes grown in the United States. Many of the varieties are similar and frequently different names are applied to the same variety.

The *Cobbler* group, which represents a class of early-maturing potatoes, contains, among other varieties, the Irish Cobbler, Early Eureka and Early Petoskey.

The *Triumph* group possesses such early varieties as Quick Lunch, Bliss' Triumph and White Bliss.

The *Early Michigan* group includes such early white-skinned varieties as Albino, Early Michigan and Early Puritan.

The *Rose* group is one of the largest, perhaps the largest, and comprises many varieties, some of which are Early Rose, Early Vermont, Late Rose, Houlton Rose, Spaulding No. 4, Extra Early Red Rose and Seneca Beauty.

The *Early Ohio* group is extensively grown and on this account is somewhat more important than the Rose group. Some of the varieties are the Early Ohio, Early Acme, Early Six Weeks and White Ohio.

The *Hebron* group contains varieties which are mostly early maturing. Some of the varieties are Early Beauty of Hebron, Early Bovee, Late Beauty of Hebron and White Elephant.

The *Burbank* group is comparatively small but rather important. It includes such varieties as Burbank, Money Maker, California Russet and Russet Burbank.

The *Green Mountain* group ranks with the Rural group in importance. Among the varieties are Carman No. 1, Empire State, Gold Coin, Green Mountain, Uncle Sam and White Mountain. These varieties have white sprouts. The Idaho Rural and Charles Downing varieties of this group have colored sprouts.

The *Rural* group contains such varieties as Carman No. 3, Peerless, Rural New Yorker No. 2, Sir Walter Raleigh and Late Petoskey.

The *Pearl* group is grown extensively in Colorado, Idaho and adjoining states. The main varieties are Pearl, People's and Blue Victor.

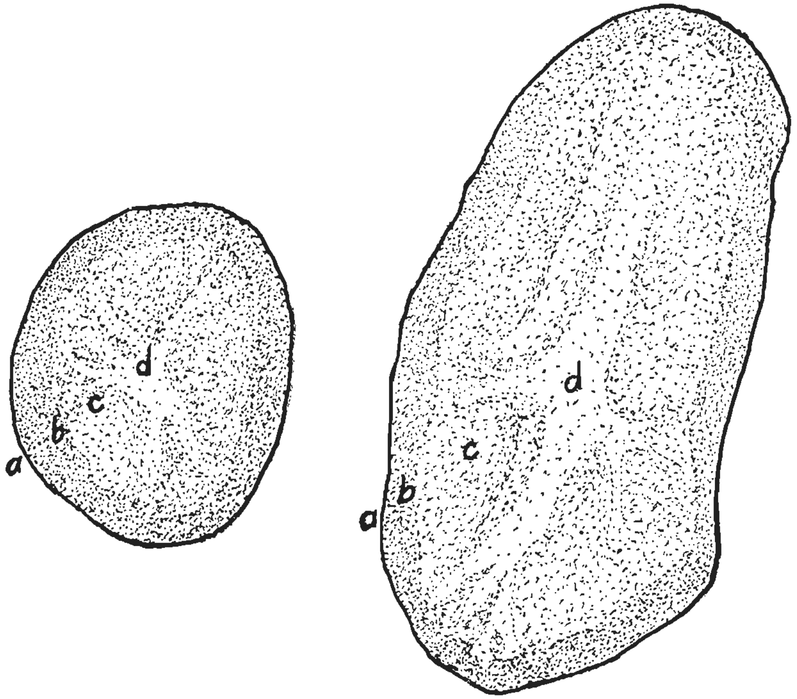

FIG. 111.—Transverse and longitudinal sections of the potato. *a*, Skin; *b*, cortical layer; *c*, outer medullary area; *d*, inner medullary area.

The *Peachblow* group is waning in popularity and the varieties are mostly late maturing. Some of the varieties belonging to this group are Early Peachblow, Jersey Peachblow, McCormick and White Peachblow.

The *Up-to-date* group is of European origin. The two varieties of this group best known in this country are Factor and Up-to-date.

Distribution of Varieties.—Potato production is at its best in the northern tier of states, especially the late or main crop. The varieties of the Green Mountain group are best suited to New England, northern New York, Long Island and New Jersey. The varieties of the Rural group lead in western New York, southern Michigan, Wisconsin, most of Iowa and portions of Minnesota. In other sections of Michigan, Wiscon-

sin and Minnesota the varieties of either group may be grown successfully. In the western states, such as Colorado, the Intermountain Basin and the Pacific Coast, the varieties of the Rural, Pearl and Burbank groups lead. In the South the varieties of the Green Mountain, Rural and Peachblow groups are used (Stuart, 1921).

In the case of the early varieties which are used for trucking purposes the Irish Cobbler leads in the northeastern part of the United States and in the southern states. In the southern states, Triumph and Spaulding No. 4 varieties are also important. In central and southern Michigan and Wisconsin the varieties of the Early Ohio and Michigan groups are grown extensively. The Early Ohio group is the favorite in Ohio, in the Kansas River Valley in Kansas, in the Great American Bottoms near St. Louis, in the Red River Valley in Minnesota and in North Dakota, South Dakota and Nebraska.

Structure and Composition.—The structure of the potato tuber is shown in Fig. 111. The tuber is composed of four parts; namely, the skin, which makes up about 2.5 per cent of the whole; the cortical layer, which includes 8.5 per cent; and the outer and inner medullary areas which together make up 89 per cent of the entire tuber. The inner medullary is sometimes called the "core." It is watery and spreads irregularly from the center.

The potato contains about 78.3 per cent water; 2.2 per cent protein; 18.4 per cent carbohydrates, mostly starch; 1 per cent ash; and 0.1 per cent fat. The composition of the different parts is given in Table CVIII taken from Fitch and Bennett (1910).

TABLE CVIII.—COMPOSITION OF THE DIFFERENT PARTS OF THE POTATO

Part	Starch, per cent	Nitrogenous matter, per cent	Water, per cent
Cortical layer and skin	19.42	1.99	74.79
External medullary area	16.29	2.14	77.44
Internal medullary area	11.70	2.31	82.16

The starch decreases toward the center while the nitrogenous matter and water increase. However, the digestible protein decreases. The cortical layer, which includes the mineral substances as well as the materials shown in Table CVIII, is the richest portion of the tuber in food value.

About one-fifth of the potato is lost in peeling. Fitch and Bennett (1910) report a loss varying from 15 to 24 per cent in peeling smooth potatoes. The loss in case of rough potatoes was 26 per cent and may be even greater.

Quality.—The quality of potatoes is modified by the character of the flesh when cooked. In quality potatoes may be mealy, soggy or waxy.

The mealy potato, which is one with a relatively high percentage of starch, is preferred in the United States. In the cooking process the starch cells burst open and a light, flaky, uniform mass results.

The soggy potato, which is one with a relatively high percentage of water and a low percentage of starch, is preferred in certain European countries. When cooked, the material remains somewhat heavy and moist instead of light and flaky.

The waxy condition is intermediate between sogginess and mealiness. This quality is often found in new potatoes, on account of the high percentage of protein relative to starch.

Botanical.—The potato, *Solanum tuberosum*, is a member of the Nightshade family. It is closely related to tobacco, the tomato and the egg plant. In this same family are found certain poisonous plants. In fact, it was once thought that the potato was poisonous and it was cultivated chiefly as a garden curiosity.

The potato is a perennial but as a crop it is treated as an annual. The tuber is an enlarged underground stem produced on the end of a stolon and not on the roots proper. Some varieties of potato produce true seeds frequently, while others seldom produce them; but the chief mode of propagation is by means of tubers. The tubers bear buds or "eyes" which are arranged in a more or less spiral form. They vary greatly in number and depth, according to the variety. They are much more numerous on the "bud end."

Roots.—The roots of potato plants have been studied by Ten Eyck (1900) in North Dakota; and it was found that in the case of the Early Ohio variety at the end of 43 days, when the plants were coming into blossom, the roots of the plants in adjacent hills, 3 feet apart each way, had met. The roots were not very fibrous but the root system had many root-hairs. The main growth of the roots was within 8 inches of the surface, but some roots reached to a depth of 18 inches. At 6 inches from the hill some of the main roots were about 2 inches beneath the surface, while midway between the rows the roots were about 3 inches beneath the surface. The depth of planting will determine to some extent the depth at which the roots will form. At the end of 72 days some of the roots had reached a depth of 2½ feet. In the case of Rural New Yorker No. 2, planted in hills 3 feet apart each way, at the end of 90 days the soil was fully occupied with roots to a depth of 3 feet. Artschwager (1918) states that the "roots penetrate the soil to a depth of 3 or 4 feet and often extend horizontally 2 feet from the plant."

Flowers.—The flowers of the potato plant are in terminal clusters. Each flower normally has five stamens and a two-celled pistil; and sometimes seeds are formed. The fruit or seed ball is round, has a diameter

of about three-eighths of an inch and possesses a structure similar to that of the tomato.

The flowers are cross-fertilized, and for this reason when the true seeds are planted the resulting progeny may be different from the immediate parent.

Uses.—The potato is used to a great extent as food, especially in some of the European countries. The tuber is prepared in various ways for human consumption. Potatoes are sometimes dried or canned, but this practice is not extensive.

The chief article manufactured from potatoes is starch, which is used for laundry purposes, for the purpose of sizing paper and textiles and for various other purposes.

Frequently potatoes are used for feed. About 40 per cent of the the crop in Germany is used for this purpose, being fed mainly to swine.

Potato Crops.—The potato may be divided into the early or truck crop, the late or main crop and the fall crops. The early or truck crop is confined to the South. The late or main crop is confined largely to the North and is of much more importance than the early crop. The late or main crop constitutes about 85 per cent of the entire crop. The fall crops may be divided into the fall crop proper and the second crop. The fall crop proper consists of late-maturing varieties used mainly for the table. The second crop consists of early varieties planted to produce seed stock for planting the early crop the next season.

Culture

Seed Potatoes.—It seems to be extremely important to use care in the selection of tubers or "seed potatoes" for planting. There is frequently a marked difference in the yielding ability and adaptability of different varieties. The presence of disease and the source of seed are also worthy of careful consideration.

Degeneracy.—Apparently potatoes degenerate and become comparatively unproductive when grown for a short time in hot climates. It is a common practice for the potato growers of the South to purchase their seed potatoes from northern growers. It may be said that seed produced at the higher elevations in the southern states give good results when planted at lower elevations. Hardenburg (1922) reports that a majority of the Long Island potato growers buy potatoes for planting mainly from Maine growers. Emerson (1914) found that seed cultivated in Nebraska rapidly deteriorated. However, seed produced under a straw mulch produced a crop practically as good as seed imported from the Red River Valley. Stuart (1913) states that northern-grown potato seeds are superior to those grown in the South. It was also found that seed potatoes secured from Scotland and grown in Vermont were superior to those

secured from England and grown in Vermont. Macoun (1905) found that seed potatoes secured from Nappan, Nova Scotia, gave better results in Ottawa, Canada, than home-grown seed.

It seems that seed potatoes grown in the northern states or in the mountainous sections of the South are more productive than those produced in the warm sections of the country.

Sun Sprouting.—Sun sprouting of potatoes before planting is recommended by some experiment stations, but the practice is not generally followed. The failure to follow the practice is probably due to the extra trouble involved rather than to the absence of increased yields. The potatoes are brought from the place of storage, placed in the light and kept at a comparatively high temperature for a period of 4 to 6 weeks before planting. The sprouts produced are short and stout and the tuber becomes somewhat *greened.*

Hardenburg (1922) finds that sun sprouting has produced little, if any, increase in yield of potatoes in New York. Hutcheson and Wolfe (1917*a*) in Virginia found as an average of the results of 2 years, that the yield of marketable potatoes was increased 8 bushels. Flagg, Towar and Tucker (1896) in Rhode Island found that sprouting potatoes before planting increased the yield 32 to 54 bushels per acre.

Type of Seed.—Hardenburg (1922) has reviewed some of the important literature in connection with survey work done in New York State. The relation of type of seed to yield was discussed under four heads: (1) large as compared with small tubers for seed; (2) whole as compared with cut seed; (3) large as compared with small seed pieces; and (4) number of eyes.

Large Tubers.—Large seed tubers seem to give larger yields than small seed tubers, according to the results presented by Hardenburg. In many of the experiments, however, the increase in yield may have been due to the increased amount of seed used per acre rather than to the influence of size of tuber.

Whole Tubers.—Whole seed are frequently reported to give better results than cut seed. However, Hardenburg (1922) has shown that in some of the experiments errors have greatly lessened the value of the results. Often when increased yields have been reported from the use of whole seed, more seed has been placed per acre. It does not seem to be definitely proved that whole seed are any more profitable than cut seed.

Small Tubers.—In some sections small tubers are planted which have been separated as culls from the crop produced in another section. In such cases the cull seed are produced from large seed each year. In these instances the use of small whole seed is probably profitable.

Large Seed Pieces.—Large seed pieces, in experiments reviewed by Hardenburg (1922), gave larger yields than small seed pieces. However,

more seeds were planted per acre in the former case. The results indicate that with closer spacing smaller seed pieces will give higher yields than large pieces spaced farther apart. It will of course require more seed to plant an acre with large seed pieces than with small ones, and the amount of seed should be taken into account in a discussion of the results.

Conclusion Regarding Type of Seed.—Hardenburg in regard to the use of different types of seed, states as follows:

> The foregoing review of the question of large as compared with small seed shows that few tests have actually proved any superior merit of large seed, except as the amount used per acre was increased. The few tests of a more comprehensive nature have indicated that equivalent amounts of smaller seed pieces, down to a minimum weight of 1 ounce, planted closer, may give even more efficient results.

Number of Eyes.—Hardenburg (1922) has reviewed the results secured in regard to the number of eyes to the seed piece in relation to yield. It seems that, as the eyes to each piece increase in number, the total yield of potatoes increases, but the yield of marketable tubers decreases. In the work of Zavitz in Canada 1-ounce seed pieces containing one, two, three, four, and five eyes, respectively, were used. Here also the total yield increased but the yield of marketable potatoes decreased. The difference in yield of marketable tubers did not vary more than 5 per cent. Apparently "nothing is to be gained by cutting to a certain minimum number in preparing seed for planting."

Immature Seed.—It is a common practice to use immature seed in planting the early or truck crop of potatoes. It is thought that such seed are more productive and ripen earlier than mature seed. The northern seed so extensively used in the South is often somewhat immature. In Europe it is also a common practice to use immature seed for planting purposes.

Stuart (1913*a*) reports results from England in which immature seed produced 100 per cent more table stock and 72 per cent more total yield than mature seed. Dewey (1916) in Idaho found that immature seed of Idaho Rurals yielded 16.7 per cent more tubers than the mature seed and that the curly dwarf present was 32.8 per cent less. The immature seed of the Peoples variety gave a yield over mature seed which amounted to 29.5 per cent. Close and White (1909) of Maryland report that the crop produced from fall-harvested seed yielded 30.7 bushels per acre more than the crop obtained from summer-harvested seed.

Time of Planting.—The time of planting is governed primarily by the date of the last killing frost. However, planting may be earlier in light soils than in heavy soils, other things being equal. The crop is usually planted to utilize the cool season of the year. In the South the potatoes are planted early so that the plants will make their growth before the

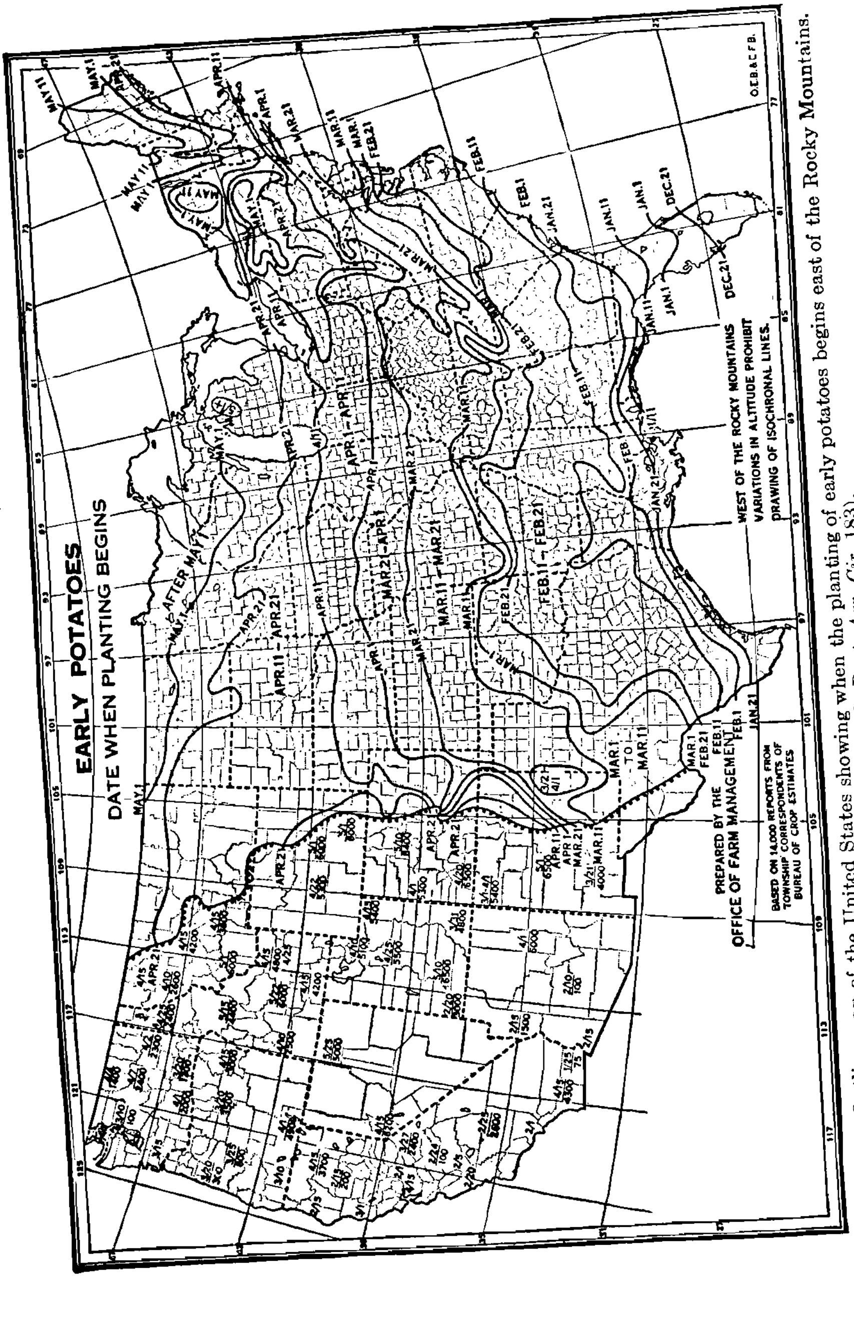

FIG. 112.—Outline map of the United States showing when the planting of early potatoes begins east of the Rocky Mountains. (*U. S. Dept. Agr. Cir.* 183).

hot midsummer. However, the crop may be planted later and the main growth made in the fall. In the North the planting is late to utilize the cool fall weather. The time of planting early potatoes is shown graphically in Fig. 112.

In brief it may be said that the early crop of potatoes is planted as soon as the ground can be worked. The time of planting the late crop varies in different sections of the country. The object is usually to utilize to the greatest extent the cool growing part of the season.

Rate of Planting.—The rate of planting will of course vary, among other things, with the size of seed piece and distance of dropping, as shown by Stuart (1921) in Table CIX.

The general rate of planting in the United States is 12 to 15 bushels per acre. In Europe the usual rate of planting is 30 to 40 bushels. That larger yields are correlated with high rate of planting is shown by Hardenburg (1922). However, after a certain limit is reached, the profit may be reduced by an increased rate of planting.

Depth of Planting.—Hardenburg (1922) has reviewed a number of experiments relative to the proper depth of planting potatoes in order to secure the highest yields. The conclusion to be drawn is that under ordinary conditions the seed pieces should be covered about 4 inches deep. This depth of planting usually gave higher yields than shallower or deeper planting. It seems that the tubers form at about the 4-inch depth; this depth may be secured by planting or by ridged cultivation.

Hardenburg, reviewing the work of Emerson in Nebraska, states that deep-planted potatoes produce more productive seed than those planted shallow. Seed from the crop planted 4 inches deep yielded better than seed from the crop planted 1 inch deep, while a depth of 7 inches was better than a depth of 4 inches.

The results in New York indicate that on the light soils the planting can be comparatively deep, while on the heavier soils it should be shallower.

Method of Planting.—The planting of potatoes in drills is more common than planting in hills. Hardenburg (1922) states that in Michigan drilled potatoes yielded 12 bushels more to the acre, in the case of the Early Ohio variety, than those planted in check rows. In case of the Rural New Yorker No. 2, the yield was 29 bushels per acre in favor of the drill method. From the drilling method Zavitz in Canada obtained an increase of 39.8 bushels per acre over planting in check rows. The results of the experiments reviewed by Hardenburg show that irrespective of the rate of planting, drilling is superior to planting in check rows.

In New York the yield from drilled potatoes was 7.9 to 23.8 bushels per acre greater than that from check-row planting. It required about [illegible] plant an acre by the former method.

TABLE CIX.—QUANTITY OF POTATOES REQUIRED TO PLANT AN ACRE AT DIFFERENT SPACINGS WITH SEED PIECES OF VARIOUS SIZES

Spacing of rows and seed pieces	Bushels of seed required, the average weight of seed pieces used being as given						
	½ oz.	¾ oz.	1 oz.	1¼ oz.	1½ oz.	1¾ oz.	2 oz.
Rows 30 inches apart:							
8-inch spacing	13.6	20.4	27.2	34.0	40.8	47.6	54.4
10-inch spacing	10.9	16.3	21.8	27.3	32.6	38.1	43.6
12-inch spacing	9.1	13.6	18.2	22.7	27.2	31.8	36.3
14-inch spacing	7.8	11.7	15.6	19.4	23.3	27.2	31.1
16-inch spacing	6.8	10.2	13.6	17.0	20.4	23.8	27.2
18-inch spacing	6.0	9.1	12.1	15.1	18.2	21.2	24.2
24-inch spacing	4.5	6.8	9.1	11.3	13.6	15.9	18.2
36-inch spacing	3.0	4.5	6.0	7.5	9.1	10.6	12.1
Rows 32 inches apart:							
8-inch spacing	12.8	19.1	25.5	31.9	38.3	44.7	51.1
10-inch spacing	10.2	15.3	20.4	25.5	30.6	35.7	40.8
12-inch spacing	8.5	12.8	17.0	21.3	25.6	29.8	34.0
14-inch spacing	7.3	10.9	14.6	18.2	21.9	25.5	29.2
16-inch spacing	6.4	9.6	12.8	16.0	19.2	22.4	25.6
18-inch spacing	5.7	8.5	11.3	14.2	17.0	19.8	22.7
24-inch spacing	4.3	6.4	8.5	10.6	12.7	14.9	17.0
36-inch spacing	2.8	4.2	5.7	7.1	8.5	9.9	11.3
Rows 34 inches apart:							
8-inch spacing	12.0	18.0	24.0	30.0	36.0	42.0	48.0
10-inch spacing	9.6	14.4	19.2	24.0	28.8	33.6	38.4
12-inch spacing	8.0	12.0	16.0	20.0	24.0	28.0	32.0
14-inch spacing	6.9	10.3	13.7	17.1	20.6	24.0	27.4
16-inch spacing	6.0	9.0	12.0	15.0	18.0	21.0	24.0
18-inch spacing	5.3	8.0	10.7	13.3	16.0	18.7	21.4
24-inch spacing	4.0	6.0	8.0	10.0	12.0	14.0	16.0
36-inch spacing	2.5	3.8	5.0	6.3	7.6	8.8	10.1
Rows 36 inches apart:							
8-inch spacing	11.3	17.0	22.7	28.4	34.0	39.7	45.4
10-inch spacing	9.1	13.6	18.1	22.7	27.2	31.7	36.3
12-inch spacing	7.6	11.3	15.1	18.9	22.7	26.5	30.2
14-inch spacing	6.5	9.7	13.0	16.2	19.4	22.7	25.9
16-inch spacing	5.7	8.5	11.3	14.2	17.0	19.8	22.7
18-inch spacing	5.0	7.6	10.1	12.6	15.1	17.6	20.2
24-inch spacing	3.8	5.7	7.6	9.5	11.3	13.2	15.1
36-inch spacing	2.5	3.8	5.0	6.3	7.6	8.8	10.1
Rows 42 inches apart:							
18-inch spacing	4.3	6.5	8.6	10.8	13.0	15.1	17.3
24-inch spacing	3.2	4.9	6.5	8.1	9.7	11.3	13.0
30-inch spacing	2.6	3.9	5.2	6.5	7.8	9.1	10.4
36-inch spacing	2.2	3.2	4.3	5.4	6.5	7.6	8.6
Rows 48 inches apart:							
18-inch spacing	3.8	5.7	7.6	9.5	11.3	13.2	15.1
24-inch spacing	2.8	4.2	5.7	7.1	8.5	9.9	11.3
30-inch spacing	2.3	3.4	4.5	5.7	6.8	7.9	9.1
36-inch spacing	1.9	2.8	3.8	4.7	5.7	6.6	7.6

In drilling potatoes farmers use both the one-man and the two man planters. Where potatoes are produced in large quantities, machine planting has displaced hand planting. A planter is profitable where 5 acres of potatoes on the average are grown.

Level Compared with Ridge Cultivation.—The most common method of cultivating potatoes is to ridge the rows. The amount of ridging varies. However, results as reported by Hardenburg (1922) show that level culture has given somewhat higher yields than ridging. This result was especially true in dry years and on light soils, but did not hold true invariably. Sometimes, especially in wet seasons, medium ridges, about 4 to 5 inches in height, are advisable.

Frequently the crop is cultivated level and at the last working a slight ridge is made. The reason often given for this practice is that the potatoes are protected from the sun.

Fig. 113.—Harvesting potatoes with a mechanical digger.

Relation of Date of Harvest to Yield.—Unless the price and other factors demand, the potato crop should not be dug until the foliage dies in the course of natural maturity. Hardenburg (1922) states from work done in Rhode Island that potatoes increased in yield from 30 bushels per acre on August 2, to 353 bushels per acre on September 22. Of this increase, 119 bushels were obtained after September 1, and there was a 50-bushel increase the last 10 days. The crop was planted on May 20. In Minnesota the Early Ohio variety of potatoes increased in yield from 10.9 bushels per acre on July 31 to 226.8 bushels per acre on August 30. The average daily gain of marketable potatoes throughout the period was 7 bushels, while the yield increased 44.7 bushels per acre during the last week. These data show the great increase in tuber yield during the last stages of growth of the plants.

Methods of Harvesting.—There are various methods of digging potatoes, such as by hand, by plowing and by the use of various types of machine diggers. A common type of machine digger is shown in Fig. 113. Hardenburg (1922) finds that when as many as 5 acres of potatoes are grown on the average annually, it is profitable to use a machine.

Storage.—Potatoes are stored in field pits, in cellars and in refrigerated storage houses. The successful storage of potatoes depends upon the quality of the product, the temperature in storage, the humidity of the air, the size of the storage pile and the exclusion of light. The proper temperature of potato storage is thought to be from 34 to 38° F.

SOME INSECT PESTS

Colorado Potato Beetle.—The Colorado potato beetle (*Leptinotarsa decemlineata*) in the adult stage is ovoid in shape, about three-eighths of an inch long, and about two-thirds as wide as long; it is yellow in color with the wing colors showing ten longitudinal black lines. The head has a triangular black spot and the thorax contains ten or more spots and other markings. The larvae are soft and Venetian red when first hatched; later they become paler.

The adult beetle enters the ground during October and hibernates there until warm weather in the spring. The beetles then emerge and the female deposits eggs on the underside of the leaves of the potato plants as soon as they appear. The eggs hatch in about one week and the larvae produced as well as the adult beetles feed on the foliage of the potato. The larvae after 2 or 3 weeks enter the soil and pupate. In 2 or 3 weeks the adults emerge and deposit eggs for the production of the second brood. The adults from the second brood hibernate during the winter, as there are but two generations each year.

Control.—In the control of the pest, a spray of Paris green or arsenate of lead is commonly used with good results. Where Bordeaux mixture is used, the poison may be mixed with the Bordeaux solution. Paris green may be added at the rate of 1 pound to 50 gallons of the water or the solution. In case water is used, 1 pound of freshly slaked lime should be added; if arsenate of lead is employed, 2 pounds of the powder or 4 pounds of the paste should be added to each 50 gallons of water or solution. Arsenate of lead adheres more readily to the leaves and is less likely to burn the foliage than Paris green.

Flea Beetle.—The potato flea beetle (*Epitrix cucumeris*) is a small, jet-black insect similar in habits and life history to the tobacco flea beetle. In addition to puncturing holes in the leaves of the plants, it is important in distributing diseases. It is controlled by the same methods as recommended for the Colorado potato beetle.

SOME DISEASES

Common Scab.—The common scab of potato is caused by the bacterium *Actinomyces chromogenus.* The disease is well known from the rough, scabby pitting produced on the tubers. The tubers may be attacked when very young or later in development. The diseased areas which are first small in size and reddish or brownish in color may spread, unite, cover the entire tuber and become darker in color.

The disease is favored by alkaline conditions and abundant moisture. Wood ashes, lime, fresh stable manure and other materials which increase the alkalinity of the soil will tend to enhance the scab injury. The parasite is apparently present in many soils and will live there for many years, especially if the soil is neutral or alkaline. The disease may be easily spread by the use of diseased tubers for seed and by the application of infested manure on the land.

Control.—In the control of the disease, tubers free of the disease should be used when practicable, rotation of crops immune to the disease followed, the use of infested manure avoided and the soil kept slightly acid when the land is infested. In case it is necessary to use diseased tubers for seed, they should be soaked before cutting for 2 hours in a solution of formaldehyde (1 pint of formalin, containing 40 per cent formaldehyde, to 30 gallons of water). Instead of the formaldehyde treatment a solution of corrosive sublimate may be used. This is made by dissolving 2 ounces of corrosive sublimate in hot water and diluting with cold water to 15 gallons. The uncut tubers should be placed in the solution for 1½ hours. The solution is very poisonous when taken internally. It also acts on metal and for this reason wooden containers should be used in administering this treatment.

Early Blight.—The early blight of potatoes is caused by the fungus, *Alternaria solani,* which attacks the leaves of the plants. The infection is evidenced by spots which are dark brown or black in color and irregularly circular in outline. They usually show a series of concentric rings giving a "target-like" effect. These spots, which usually appear about the time the tubers begin to form, may spread over large areas of the leaf surface and thus cause the death of the leaves while the stems are still green. The progress of the disease, in contrast to that of late blight, is slow; usually 3 or 4 weeks elapse before all the leaves are dead. Moisture aids the spread of the disease while drought will check it completely.

Infection, according to Rands (1917), may take place either through the stomata or through the cuticle. It is probable that the flea beetle aids in increasing infection by carrying spores and inoculating the wounds it makes. The disease is carried over winter by spores and mycelia in the remains of the former crop.

In the control of the disease, Rands (1917) recommends spraying with Bordeaux mixture (5-5-50) each week. This spraying should

begin when the plants are 6 to 8 inches high and should continue throughout the season of growth. Crop rotation is also of benefit since infection takes place from the spores which have overwintered in the soil on the dead vines.

Late Blight.—Late blight of potatoes is caused by the fungus *Phytophthora infestans.* It usually appears in the latter part of the growing season and attacks the leaves, stems and tubers. It is much more prevalent in wet seasons. The disease shows on the leaves as dark, water-soaked areas, which may appear on any part of the leaf. The spots frequently begin at the tip or edge of the leaf and spread until the whole leaf is affected. In moist weather the spots rapidly enlarge, and on the lower side of recently affected areas usually a fine white mildew appears. The stem may become affected in a like manner, or sometimes the disease first attacks the stem and then the leaves.

The disease may attack the tubers, and those lying near the surface of the ground are the first to become affected. On the affected tubers are produced discolored, water-soaked areas which may be small, or in moist soils may sometimes extend over a large part of the surface of the tuber. These affected areas become sunken by digging time or in storage and the flesh has a rusty brown color. The flesh is affected to a depth of about one-fourth to one-half of an inch. This condition is known as "dry rot." While in storage the fungus sometimes spreads from affected tubers to healthy ones. The late blight fungus develops best under cool, moist conditions. Tubers will rot but little in storage from late blight infection, if kept in a dry place and held at a low temperature (40° F. or below). Other fungi or bacteria may enter the affected areas and produce a soft, disagreeably smelling condition known as "wet rot." The disease lives from year to year on the affected tubers, and spreads to healthy plants from the vines produced by affected tubers.

Babcock (1917) at the Ohio Experiment Station states that the disease does not live over in the soil and that the outbreak comes only from planting diseased tubers.

Control.—In the control of the disease, spraying with Bordeaux mixture (5-5-50) each week is recommended. The spraying should begin when the plants are 6 to 8 inches high and should continue throughout the season of growth. Crop rotation and the use of disease-free tubers for planting are good preventive methods.

CHAPTER XXXIX

SWEET POTATO (Ipomoea batatas)

The sweet potato is adapted to regions having a growing period of at least 4 months with warm days and nights, plenty of sunshine and moderate rainfall. The largest yields are secured when rainfall is abundant in the early part of the growing season; and less plentiful during the latter part.

Well-drained soils are necessary for highest yields. The crop thrives best on sandy loam soils but it can be grown on a wide range of soils.

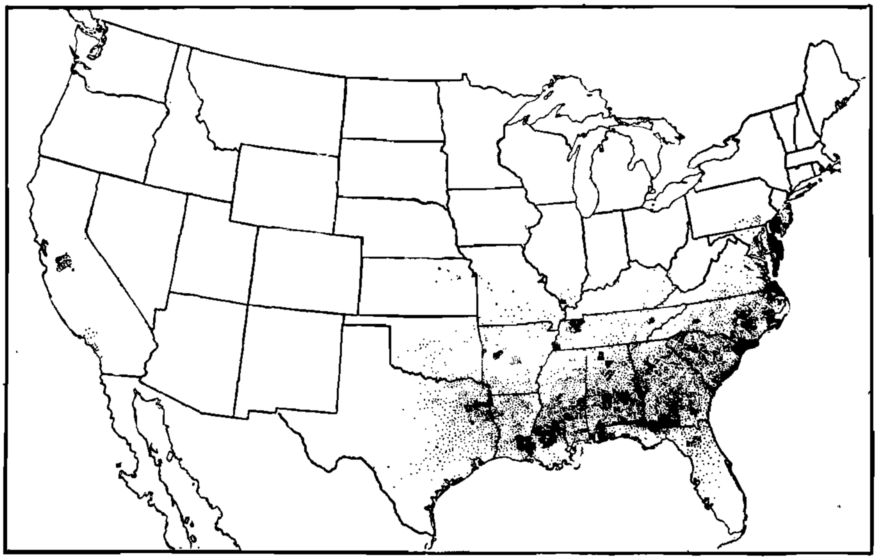

Fig. 114.—*Outline map of the United States showing the sweet potato acreage. Each dot represents 100 acres.* (*U. S. Dept. Agr. Farmers' Bul.* 999).

Production in the United States.—Approximately 90 per cent of the sweet potato crop is grown in the southern states. The sweet potato acreage is shown in Fig. 114. In the portion of the area which corresponds approximately to the cotton belt, the sweet potato crop is grown on a commercial scale, while north of that section, with the exception of New Jersey, Delaware and limited areas in Maryland, the crop is grown chiefly for home use.

In the United States as a whole, the average annual production for the 5-year period, 1910 to 1914, was 57,117,000 bushels, with an

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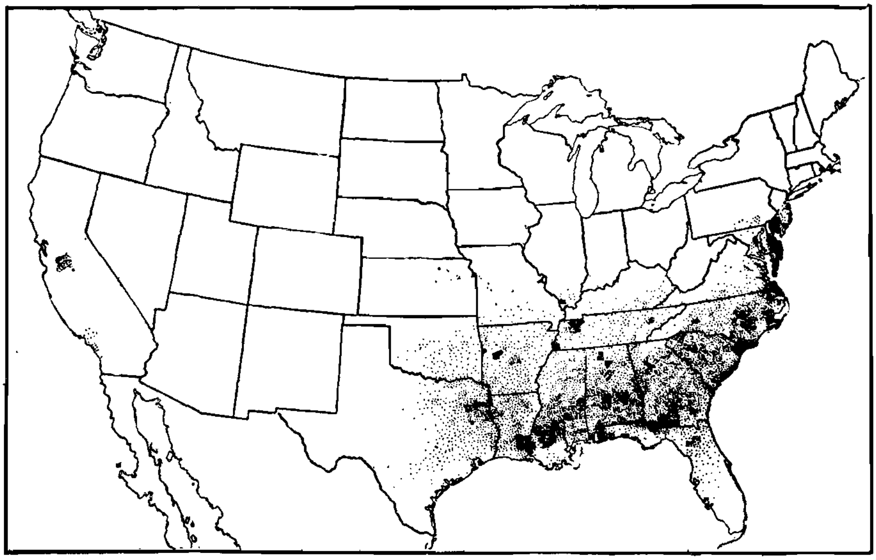

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In the United States as a whole, the average annual production for the 5-year period, 1910 to 1914, was 57,117,000 bushels, with an

average acre yield of 93.5 bushels; during the period, 1915 to 1919, the average annual production was 83,093,000 bushels and the average acre yield was 96.6 bushels.

The five states, Georgia, Alabama, Mississippi, North Carolina and Texas, produced 55,323,000 bushels, or 53.2 per cent of the entire crop in 1920.

Historical.—The early history of the sweet potato is but little known, but it is regarded as a native of South America. Columbus found the crop being grown by the Indians in Cuba; and by later Spanish expeditions it was also found growing in Mexico and South America. Sweet potatoes were probably cultivated in Virginia as early as 1610 and in 1705 a detailed description was given of the sweet potatoes grown in Virginia. The increase in production the United States in the last few decades has been rapid until at the present time sweet potatoes rank second only to potatoes as a commercial truck crop.

Varieties.—There are about twelve varieties of sweet potatoes important from the market standpoint. The variety chosen will depend on the market demands and the purpose for which the potatoes are to be used. As a rule the northern markets prefer a dry, mealy potato of the Jersey group. However, some of the moist-fleshed varieties, such as the Nancy Hall and the Dooley, are satisfactory. The southern market, in contrast to the northern market, usually prefers the moist-fleshed varieties such as the Nancy Hall, Southern Queen and Porto Rico. The Dooley and Pumpkin are also commercially popular. When the crop is grown for stock feed, such varieties as the Yellow Strassburg, Red Bermuda and White Belmont are important.

The main varieties which are dry and mealy are the Big Stem Jersey, Yellow Jersey, Red Jersey and Red Carolina. The leading varieties of the moist-fleshed group are the Nancy Hall, Southern Queen, Pumpkin Georgia, Porto Rico and Dooley.

Description.—The sweet potato (*Ipomoea batatas*) belongs to the morning-glory family, *Convolvulaceae*. It is a perennial but under cultivation it is treated as an annual. The plant is viney although the varieties are sometimes classed as viney and vineless. The latter term refers to varieties having short, upright vines. The stems are prostrate and frequently during the latter part of the season become rooted at the nodes. The triangular leaf varies much in shape and the differences are used to some extent in classification.

The edible portion of the sweet potato plant is an enlarged root, in contrast to the potato, which is a tuber or enlarged underground stem. The sweet potato rarely produces flowers in this country. The blossoms when produced are purplish in color and in shape resemble those of the morning glory.

The sweet potato is frequently referred to as a yam, but this nomenclature is erroneous, as the word "yam" belongs to another genus of plants (*Dioscorea*).

Uses and Composition.—The chief use of the sweet potato is for human food. Sweet potatoes are also used to some extent for feeding live stock. The crop may be utilized for making starch, syrup and alcohol. The roots contain about 16 per cent starch and 4 per cent sugar, or a total of 20 per cent of alcohol-producing material. A bushel of sweet potatoes should make approximately 1 gallon of industrial alcohol. The vines, when properly cured, make a medium grade of hay.

The composition of sweet potatoes is shown in Table CX taken from Langworthy (1917).

TABLE CX.—CHEMICAL COMPOSITION OF SWEET POTATOES

	Water, per cent	Protein, per cent	Fat, per cent	Carbohydrates		Ash, per cent
				Sugar, starch, etc., per cent	Crude fiber, per cent	
Sweet potatoes, edible portion	69.0	1.8	0.7	26.1	1.3	1.1
Sweet potatoes as purchased	55.2	1.4	0.6	21.9	...	0.9

CULTURE

"Seeds."—The selection of good "seeds" or roots for propagation purposes is important. The best place for selection is in the field, as here the vine growth, yield per hill and the size and shape of the potatoes can be studied. It is very desirable that potatoes be selected from productive hills, that they be free from disease and well shaped.

Propagation of Plants.—Sweet potatoes are grown either from vine cuttings or from slips or shoots produced from roots. When the buds or eyes of the potatoes are placed in beds under the proper conditions of heat and moisture the slips or shoots develop. It usually requires 6 to 8 bushels of seed potatoes to produce sufficient shoots to set an acre from the first pulling. In case two or three crops of slips are to be utilized, then a sufficient quantity will be 3 to 4 bushels of potatoes.

The vine cuttings are secured by cutting sections of vines from plants produced by the slips. Vine cuttings are often thought to be preferable to slips or shoots. Newman (1902) in Arkansas found that the 2-year average yield of marketable potatoes from vine cuttings was 7.9 bushels per acre greater than that from slips. However, the difference in favor

of the vine cuttings was only 4.5 bushels when the total yield was considered. Vine cuttings are particularly desirable for the production of seed potatoes as the cuttings are usually free from seed-borne diseases.

Bedding.—The potatoes which are to be used to produce slips are usually bedded about 6 weeks before the slips are to be needed. The roots are placed, with the ends pointing in the same direction, in especially made beds and the development of the slips is stimulated by furnishing the proper amount of heat and moisture.

There are several kinds of beds used, but a common one is the manure-heated bed. A protected place is selected and an excavation made in the ground to a depth of from 12 to 18 inches. Fresh horse manure is placed in the bottom and thoroughly trampled until the depth is 8 to 12 inches. The manure is then covered with 3 to 4 inches of sandy soil and the bed covered and allowed to heat. After the maximum temperature has been reached and cooled down to 80 to 85° F., a process which usually requires about 4 days, the potatoes are placed in the bed and covered to a depth of 1 or 2 inches with sand. After planting the bed should be kept well watered but not saturated.

Pulling the Slips.—The slips should be pulled in such a way as not to disturb the potatoes in the bed. The best methods to accomplish this result is to hold one hand on the ground above the potato and pull the slips with the other hand. The placing of small mesh wire over the potatoes before covering will aid in keeping them in place while the slips are being pulled. It is advisable to dip the roots of the slips as pulled into a thin paste made of clay and cow manure. This process is called "puddling." They may then be packed in an upright condition and taken to the field for planting. To stimulate new growth and to settle the soil the bed should be watered after the slips are pulled. If it is desirable to promote vine growth in order to secure vine cuttings from the plant bed, watering may be done with a solution of nitrate of soda (1 ounce of nitrate of soda to 1 gallon of water).

Ridge and Level Planting.—The sweet potato crop is usually planted on ridges. The ridges are made with the plow and just before planting they are commonly leveled on top. In the cultivation of the crop, the ridge is maintained. However, the crop is sometimes planted level and it is probable that this method will give about as good results as ridge planting except where the land is not well drained. Newman (1902) in Arkansas reports the 2-year average yield of marketable potatoes per acre for different kinds of planting as follows: level, 183.4 bushels; in 3-inch ridges, 191.8 bushels; in 6-inch ridges, 174.6 bushels; and in 9-inch ridges, 152.2 bushels.

Planting the Slips.—The slips should not be set in the field until the danger of frost is over. However, they should not be set so late that they will not have sufficient time to fully develop before the fall frosts.

It usually requires about 3 to 4 months for the potatoes to reach full development.

A rainy period is preferable for setting the slips, but good results may be secured from setting in dry times by watering the slips when they are set out.

Hand planting is generally followed when the crop is grown on a small scale, and in such cases one person may distribute the slips while another sets them. The holes are usually made for the slips with a sharpened stick or garden dibble. An experienced man can set 1 acre of slips each day, if the slips are distributed by someone else.

Where the crop is grown on an extensive scale, transplanting machines are used. As a rule 4 or 5 acres can be planted with a machine in a day.

Rate of Planting.—The rate of planting will vary with the variety and the productivity of the soil. The Southern Queen and Porto Rico varieties, which produce a large vine growth, should be allowed more room than a variety like the Yellow Jersey, which makes a small vine growth. On good sandy loam soils the rows are frequently 28 to 30 inches apart and the slips 14 to 18 inches apart in the row. On the poorer, sandy soils the rows are often 32 to 48 inches apart and the slips 14 to 24 inches apart in the row.

The number of slips required to plant an acre will, of course, depend on the distance of planting. If the rows are 30 inches apart and the plants 14 to 18 inches apart in the row, 10,000 to 12,000 slips will be required to plant an acre.

Cultivation.—The sweet potato crop is usually cultivated with the same implements used in cultivating other crops. As a rule, some form of one-horse cultivator is used and hand hoeing should be given when necessary. When the vines meet between the rows, cultivation usually ceases; but at the last cultivation it may be necessary to lay the vines aside by hand. However, some cultivators are equipped with a vine-lifting attachment.

Harvesting.—If the crop is intended for the early market, harvesting begins as soon as the potatoes reach a marketable size. The main crop should be harvested before freezing weather since the potatoes are in some danger of being injured if the vines are frozen. However, a light frost may cause no material damage to the roots. It is advisable, in case the vines are frosted, to cut them at once even though the crop is not to be harvested immediately.

Tools for Harvesting.—The kind of implement used to harvest the crop will depend largely on the area to be harvested. When the crop is grown for home use, an ordinary spading or hoe fork is generally used for getting the potatoes from the ground. The ordinary turn plow has been modified in many ways for harvesting the sweet potato crop. Usually a rolling coulter is attached; and when this attachment is made, the first

furrow is made with the land side next to the row and the next furrow is so made as to turn the potatoes from the ground. Again two rolling coulters may be attached and in such case, one furrow completes the operation, the rolling coulters being used to cut the vines. There are also special implements for digging the crop. The potato digging machines are not satisfactory for digging sweet potatoes, as the sweet potatoes are likely to become more or less bruised.

After the sweet potatoes are dug, they should be placed on top of the soil and allowed to dry. As far as practicable care should be exercised in handling to prevent breaking the skin and bruising.

Storage.—The essentials of good storage are that the potatoes be (1) free from diseases; (2) matured before digging; (3) carefully handled; (4) well dried or cured after being stored; and (5) kept at a uniform temperature after curing. Throughout the storage period proper ventilation is important.

CHAPTER XL

PEANUTS (Arachis hypogaea)

The peanut, also known as "goober," "goober pea," "ground pea," "groundnut" and "pindar," is an important crop in about a dozen states in the South. It is, properly speaking, a pea rather than a nut. The term nut has perhaps been added since the pea has a shell and a flavor similar to the shells and flavors of many true nuts.

Peanuts are produced in the Orient, Africa, Mediterranean Europe and the southern part of the United States. Peanuts are important in

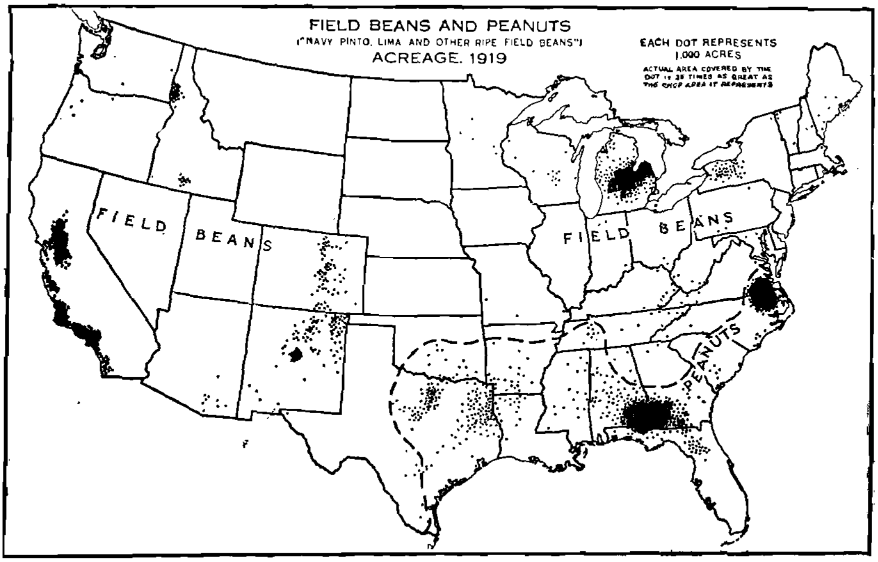

FIG. 115.—The acreage of peanuts shown on the map does not include the crop "hogged off." *The peanuts for human consumption are grown mostly in the North Carolina-Virginia district; those grown in Georgia and Alabama are largely fed to hogs or made into peanut butter.* (*U. S. Dept. Agr. Yearbook*, 1921).

international trade and in 1921 the imports for the United States amounted to 35,640,000 pounds of shelled peanuts and 4,524,000 pounds of unshelled. The exports from the United States amounted to 14,493,000 pounds.

Production in the United States.—Peanut production on a commercial scale is limited to the southern states. The bulk of the peanut crop produced in Virginia and North Carolina is used for human consumption, while the peanuts grown in the states farther south are to a great extent "hogged-off, or used for the production of oil.

Figure 115 shows the acreage of peanuts in the United States in 1919. The production of peanuts in the United States as a whole for 1919 was 783,273,000 pounds; in 1920 the production was 841,474,000 pounds; and 1921 the production was 829,307,000 bushels. The average acre yield during these years was 691.9, 712.5 and 683.1 pounds, respectively.

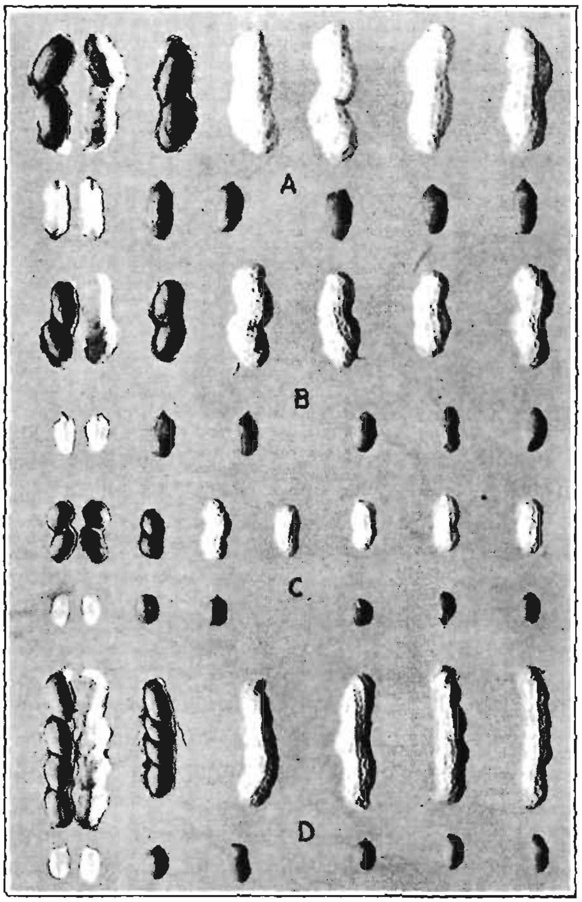

FIG. 116.—Commercial types of peanuts. *A*, Virginia Bunch, or Virginia Runner; *B*, African, or North Carolina; *C*, Spanish; *D*, Tennessee Red. (About one-half natural size.) (*U. S. Dept. Agr. Farmers' Bul.* 431).

The three states, Alabama, Virginia and North Carolina, produced 18,008,410 bushels, or 65.6 per cent of the entire crop in 1919.

Historical.—The peanut originated in America and it is probably a native of Brazil since six or seven closely allied species are found there. The fact that seeds were found in Peruvian tombs at Ancon indicates its antiquity in America. The plant is cultivated in practically all hot countries but it was not mentioned by the Greek, Latin or Arabian authors.

The peanut was brought to the United States during the early days of colonization, but it did not become commercially important until about 1870. The growth was gradual from that time to about 1900 when the cultivation received a rapid impetus due to the spread of the boll weevil in the South. In 1909 there were 870,000 acres of peanuts grown—an increase of 68 per cent over the production of 1900. In 1915 there were 1,220,000 acres and in 1919 there were 27,449,930 acres.

Classification.—Peanuts may be divided into two types: large podded and small podded. These types are subdivided into bunch and runner sorts. There are in all nine or ten distinct varieties of peanuts grown in the United States. Peanuts may be classified as follows:

Size of Pods	Type of Growth	Varieties
Large	Runner	Virginia Runner North Carolina African
	Bunch	Virginia Bunch
Small	Bunch	Spanish Small Spanish Improved Spanish Valencia Tennessee Red Georgia Red

In the bunch type the pods are clustered about the base of the plant. In the runner type the pods are scattered along procumbent rooting stems. The large-podded varieties are used chiefly for roasting and confectionery purposes. The small-podded kinds are used for shelling, oil making and hog feeding.

The Virginia Runner and Virginia Bunch varieties weigh 22 pounds to the bushel, the Spanish variety weighs 30 pounds, while other varieties range between these weights according to the size and filling of the pods.

Regions.—The peanut will adapt itself to a wide range of climate if the soil conditions are favorable. The preferable climate is one with a growing season of 120 to 140 days, moderate rainfall during the growing season, plenty of sunshine and a comparatively high temperature. Usually the best results are secured when the average annual rainfall is from 42 to 54 inches, but the crop can be produced with more or less water than this amount.

Light sandy loam soil is the most suitable kind for the production of the largest quantity of marketable peanuts to the acre. Sandy soils produce, other things being equal, peanuts of the highest quality, but the yields are somewhat better on the sandy loams. Dark-colored soils stain the hulls and lower the market price. When the peanuts are not to be sold, but are to be used for hog feeding or some similar purpose, almost any kind of soil, with the exception of the very heavy

types, may be used. For peanut growing it is very essential that the soil be drained.

The region having climate and soils most suitable for peanut production is shown in Fig. 117.

In Virginia and northeastern North Carolina the Virginia Bunch and Virginia Runner varieties predominate. In the Gulf Coast region, Oklahoma and Arkansas, the Spanish variety is most widely grown.

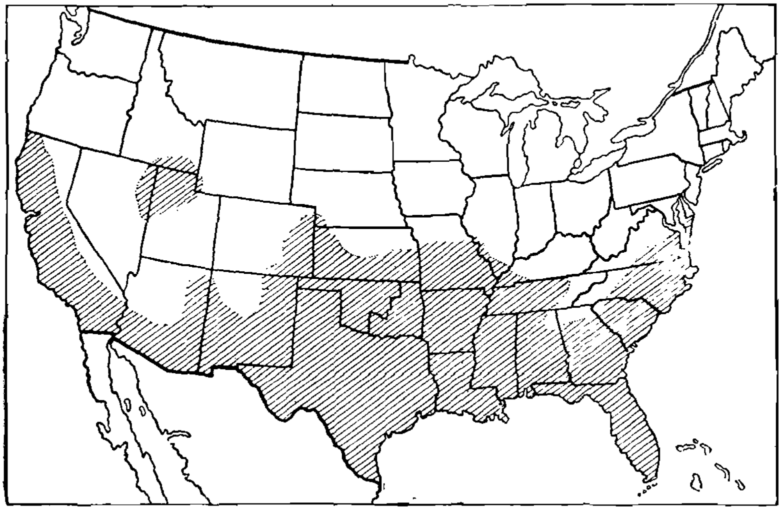

FIG. 117.—Outline map of the United States, showing the area adapted to the production of peanuts. (*U. S. Dept. Agr.*)

Composition.—According to results secured by Batten (1918) in Virginia, the percentage of shell or hull in the Virginia Bunch variety is 26.92 per cent; Virginia Runner, 14.70 per cent; and Spanish, 17.74 per cent. However, Bailey and LeClerc (1917) report slightly different results. These investigators report that the Virginia varieties average about 35 per cent hull and the Spanish kinds 30 per cent. Reed (1922) working with both Spanish and Virginia Runner varieties found that as an average of all the tests the percentage of hulls was 24.5 and the percentage of meat 75.5.

The composition of the different portions of the peanut plant and some of its by-products is shown in Table CXI. The analyses of the hay and vines are taken from Brown (1891) and the remainder are from Reed (1922).

Botanical.—The peanut (*Arachis hypogaea*) is a member of the Papilionaceae or pea family. It is an annual; and the plants grow from 1 to 2 feet high and produce angular, hairy stems with spreading branches. Some of the varieties produce branches which are compara-

tively long and prostrate, while those of other varieties are short and upright. The flowers, which are small and yellow, are borne in the axils of the leaves. There are two kinds of flowers: the male or staminate flowers, which are relatively showy; and the hidden or cleistogamous flowers. The male flowers soon wither and fall. After fertilization a peduncle bearing a female flower elongates, grows downward, and

TABLE CXI.—CHEMICAL COMPOSITION OF THE PEANUT AND SOME OF ITS BY-PRODUCTS

Peanut	In water-free substance, per cent					
	Water	Ash	Protein	Fiber	Nitrogen-free-extract	Fat
Hay	7.83	17.04	11.75	22.11	46.95	1.84
Vines	6.25	6.02	13.48	29.16	36.28	15.06
Whole peanut	6.20	4.00	36.60	24.30	21.50	7.30
Hulls	7.90	3.00	6.80	62.30	17.10	2.90
Cake and meal	7.30	5.60	46.90	9.50	22.40	8.50
Skins	7.10	3.20	16.90	10.80	37.50	24.60
Germs	5.60	3.10	29.10	4.50	12.00	45.40
Meat	4.80	2.40	29.80	2.80	12.90	47.20

pushes the sharp pointed ovary into the ground. The development of the pod takes place entirely under the ground. If the ovaries are prevented from entering the ground, no pods are produced. The plant has a small tap root with many strong branches. The roots are cinnamon yellow in color and usually abundantly supplied with nodules.

Uses.—The crop is used in a great number of ways and its importance is increasing. As a human food the peanut is not only eaten from the shell, but also in the form of salted shelled peanuts and blanched peanuts. It is also used in candies and brittle, and in the form of butter. Large quantities of oil are also expressed from the seed.

Peanut butter is a highly nutritious food, since it contains 29.3 per cent protein, 46.5 per cent fat, 17.1 per cent carbohydrates and 5 per cent ash, and has a food value of 2,825 calories per pound.

Peanut oil is used extensively at the present time. Spanish peanuts contain, according to Thompson and Bailey (1916), 52.5 per cent oil, and Virginias 43.3 per cent. On this basis, the trash being taken into consideration, a ton of unshelled Spanish peanuts produces about 700 pounds of oil; a ton of Virginias, 500 pounds. A by-product of peanut oil manufacture is peanut meal; a ton of shelled peanuts produces 750 pounds of meal.

The peanut crop is also used to a large extent for feeding live stock. The tops of the plants may be cut for hay and pods removed from the ground afterwards, or the crop may be pastured by hogs. The hay yield varies from 1 to 2 tons per acre and compares favorably in feeding value with good clover hay. Peanut straw, which is the herbage left

FIG. 118.—Peanut plant showing flowers and elongated peduncles. (*U. S. Dept. Agr. Farmers' Bul.* 1127).

after the pods have been removed, has a somewhat higher feeding value than peanut hay, but is not so bright or palatable. The use of the peanut crop for fattening hogs is important, especially in the Gulf Coast states.

CULTURE

Seed.—The use of good seed of peanuts, as with other crops, is very important. The use of inferior seed has been the cause of many poor yields of peanuts. Seed should be selected from plants producing a large number of mature pods. The seed after harvesting should be cured and handled in such a manner as to retain their vitality. This result can be secured by proper stacking and storing in a dry place.

In the planting of the large-podded varieties, shelled peanuts are used; but, in the case of the Spanish varieties, the unshelled peanuts are planted. In many instances where peanuts are planted unshelled, they are soaked in cold water from 12 to 24 hours before planting and dried 1 or 2 hours after soaking. Shelled nuts should never be soaked before planting.

Time of Planting.—Peanuts should not be planted until after danger of frost is passed and the ground is beginning to warm. If a good stand is to be assured the seeds should germinate promptly after being planted. The commercial crop is planted somewhat later than corn and beans. The earlier varieties, such as the Spanish, may be planted somewhat later than the later ripening varieties, such as the Virginia. Planting usually takes place from April 10 in the Gulf Coast states to May 10 in the Virginia-North Carolina district. However, in the far South the early varieties may be planted as late as July 1 with fair results.

Rate of Planting.—In case unshelled nuts of small-podded varieties are used, it requires 32 to 48 pounds to plant an acre, according to the

FIG. 119.—A field of peanuts.

distance of planting. If shelled seeds are used, 23 to 34 pounds will be required. The large-podded varieties are seeded in the shell and the rate of planting varies from 24 to 30 pounds per acre.

The distance of planting varies with the tools used in cultivation, character of soil and the variety of peanuts grown. The distance between rows is usually about 3 feet but it varies from 2½ to 3½ feet. The distance between hills in the row also varies. Beattie (1920), as a result of experiments conducted at Florence, South Carolina, has recommended planting the Spanish and Virginia Bunch varieties 3 inches apart in rows 30 inches apart. This investigator gives the planting distances for peanut varieties as shown in Table CXII.

TABLE CXII.—PLANTING DISTANCE FOR DIFFERENT VARIETIES OF PEANUTS

Variety	Distance, in.		Variety	Distance, in.	
	Between rows	In rows		Between rows	In rows
Spanish	32 to 38	7 to 10	Virginia Bunch	32 to 38	8 to 12
Valencia, Tennessee Red, Georgia Red	32 to 42	8 to 12	Virginia Runner	36 to 42	12 to 18
			North Carolina	34 to 38	12 to 15
			Africa	36 to 42	12 to 18

Depth and Methods of Planting.—The depth of planting varies with the soil. On light sandy soils the usual depth is from 1½ to 2 inches, while on heavier soils the depth varies from 1 to 2½ inches. On moist soil the depth suitable is less than on dry soil.

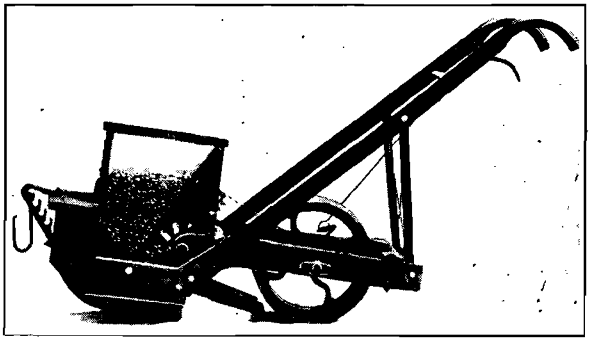

FIG. 120.—A 1-horse peanut planter. (*U. S. Dept. Agr. Farmers' Bul.* 1127).

The planting is usually done by machines, one type of which is shown in Fig. 120. Planting is sometimes done by hand but this method is not so economical as machine planting when a commercial crop is grown.

Cultivation.—The crop requires cultivation similar to that recommended for corn, but hand hoeing is often necessary. Frequent cultivations should be given from the time the rows can be followed until the plants begin to form pods; often the first cultivation is done by harrowing diagonally across the rows just as the plants are appearing.

Time of Harvesting.—The crop should be harvested before frost. The proper time for harvesting the crop may be recognized by a slight yellowing of the foliage and by an examination of the pods. If the pods have begun to shed at the base of the plant and if the inside of the shells has begun to color and show darkened veins, the crop is ready to harvest. The pods will not all mature at the same time, but harvesting should be done when the majority have reached maturity.

Methods of Digging.—There are various ways of digging the crop. A common method is to remove the moldboard from the ordinary turn plow and run the share beneath the row of peanuts. Thus the tap roots are cut off and the plants loosened. The plants can then be removed with a fork and placed in bunches. The object of any implement is to cut off the roots and loosen the plants. Special machines for digging and bunching peanuts are on the market. The regular horsepower potato diggers with elevators are also used with good results.

FIG. 121.—Poles around which stacks of peanuts are to be built. (*U. S. Dept. Agr. Farmers' Bul.* 1127).

Stacking.—After digging, the plants are allowed to lie on the ground until the leaves are slightly wilted; wilting ordinarily requires about 3 or 4 hours.

The vines are then stacked around poles to which two cross-pieces have been nailed a few inches above the ground. The poles are usually 7 feet long, 3 to 4 inches in diameter and sharpened at both ends. The cross-pieces should be 14 to 18 inches long. It requires 15 to 30 poles for an acre of peanuts, according to the yield. The peanuts are stacked with the nuts next to the pole and the branches out. The stacks should be made slender and tapering toward the top to aid in shedding water. Each stack is usually topped with grass or weeds to shed rain.

When the peanuts are intended for the market the curing process in the stacks requires about 6 weeks. If the crop is to be fed to live stock, it may be allowed to cure 2 to 4 weeks in the stacks; then it may be stored in barns or sheds.

Picking.—Picking is usually done in the fall during the months of October, November and December. The pods should be thoroughly cured and the vines dry and brittle. Most of the peanuts are picked by machinery at the present time, but formerly hand picking was the more common method. The machine picks about 250 bushels of peanuts per day on the average. To prevent discoloration and consequent reduction in market value the picked pods should be kept free from dampness.

CHAPTER XLI

SOME CULTIVATED GRASSES

According to Piper (1922), there are about 6,000 species of grasses in the world. Of these only approximately 60 are of importance in cultivation, and not over 20 wild species are abundant or valuable in any one section. The discussion in this chapter will be limited to a few of the more important species.

TIMOTHY

Origin and History.—Although timothy (*Phleum pratense*) was first cultivated in the United States, it is a native of the Old World. The name timothy comes from Timothy Hansen who in about 1720 introduced the grass into Maryland. The name "Herd's grass" was given this plant because it was found growing in New Hampshire in 1700 by John Herd. The fact that the name "Herd's grass" still persists in the New England states causes some confusion, as redtop is called Herd's grass in the South. Timothy is by far the most important hay grass in the United States.

FIG. 122.—Timothy (*Phleum pratenca* Linnæus). (*U. S. Dept. Agr. Farmers' Bul.* 1254).

Description.—Timothy is the best known grass in this country and belongs to a species in which there are eleven closely related forms, one of which is the mountain timothy (*Phleum alpinum*). The plant is a perennial, semi-bunch grass. Timothy is primarily a hay plant and does not stand grazing well; however, when there is considerable aftermath produced, the crop may be grazed profitably.

Timothy differs from most other grasses in that the lower internodes, sometimes one and sometimes two, are often enlarged and referred to as "bulbs" or "corms." These bulbs or corms are in reality only thickened internodes. The corms are of annual duration forming in early summer and dying the next year when the plants mature. Oakley and Evans (1921) have shown that in some instances timothy at times produces

stolons and frequently there are two types of underground rooting stems. They describe the latter as follows:

One type develops when the shoot that produces the new plant is covered with soil early in its growth. Some of the unelongated internodes connecting the shoot with the parent plant elongate, thereby pushing the shoot to the surface of the soil. Roots grow from the nodes between the elongated internodes.

A second type of underground rooting stem is produced when timothy plants with growing culms are covered with soil. Buds that sometimes form on the culms of these plants frequently develop into shoots and ultimately into independent plants. The culms then become underground rooting stems.

Fig. 123.—Redtop (*Agrostis alba* Linnaeus; *Agrostis palustris* Hudson). (*U. S. Dept. Agr. Farmers' Bul.* 1254).

Adaptation.—Most of the timothy crop is produced in the northern half of the country east of the Missouri River.

Timothy is a northern grass and is adapted to cool, humid climate. It does not do well in the United States south of latitude 36° north except at high altitudes. It will not thrive under hot, humid summer conditions; and under such conditions weeds, such as crab grass, compete with it strongly.

The crop is best adapted to the heavier soils, such as clays and loams, and will not thrive on dry or sandy soil regardless of its productivity. On the other hand, timothy thrives best where moisture is abundant and under such conditions stands may be often obtained with little attention to the preparation of the seedbed. Timothy is now being grown under irrigation.

Uses.—The importance of timothy as a hay crop is shown by the fact that the extent of this crop is four times that of all other hay grasses combined and equals all other hay plants, including clover and alfalfa. It is grown to a large extent with clover for hay.

REDTOP

Origin and History.—In Pennsylvania and in the southern states redtop (*Agrostis alba* Linnaeus; *Agrostis palustris* Hudson) is called Herd's grass, which is the name given to timothy in the New England states. Redtop is not a native of the United States and the first record of its cultivation in this country was in 1807. It is said to have been grown

in France in 1761. Redtop is a native of the Old World and is found over most of Europe, Asia, in the western parts of Africa and in Abyssinia.

Description.—Of the many grasses belonging to the genus *Agrostis*, redtop is the only one that is of much importance as a hay plant. It is a perennial grass, with a creeping habit of growth, being stoloniferous; and it makes a coarse, loose turf. The rootstocks are shallow, vigorous and about 2 to 6 inches long. The stems are frequently decumbent at the base, and the nodes root freely. Redtop matures about with timothy and is frequently sown in mixtures with the latter grass. The panicles, which are reddish in color and loosely pyramidal in shape, are very characteristic.

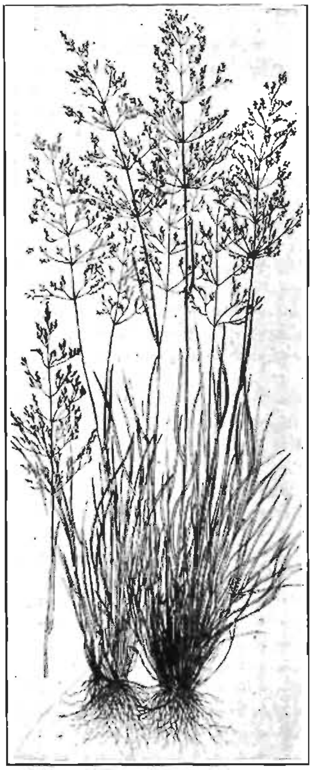

Fig. 124.—Rhode Island Bent (*Agrostis tenuis* Sibthorp; *Agrostis vulgaris* Withering). (*U. S. Dept. Agr. Farmers' Bul.* 1254).

Adaptation. — Probably no cultivated grass has wider adaptation to both climate and soil than redtop. It will thrive in all parts of the United States with exception of the drier areas and the extreme South. It is found growing, however, from Canada to the Gulf of Mexico and from New York to California.

Redtop is at least as cold resistant as timothy and withstands summer heat to a much greater degree. It is not adapted to growing in shade and is but rarely found under such conditions.

The crop apparently shows but little preference as to soil type so long as plenty of moisture is present; but the heavier soils allow more luxuriant growth. Redtop thrives best on moist or wet soils, but in the face of this fact the plant can endure much drought and on poor uplands will do better than most grasses. Not only is redtop tolerant of acid soils but in fact seems to thrive better where lime is deficient.

Uses.—The main uses of redtop are: (1) a hay crop on wet or sour lands; (2) a part of pasture mixtures under humid conditions, especially on the non-limestone soils; (3) a soil binder; and (4) an ingredient in hay mixtures which are to be fed on the farm.

BENT GRASSES

In addition to redtop (*Agrostis alba*) there are two other important cultivated species of the genus *Agrostis;* the two bent grasses, Rhode

Island Bent (*Agrostis vulgaris*) and Creeping Bent (*Agrostis stolonifera*), both natives of Europe. These two grasses resemble redtop, but differ from the later in being much smaller and in having more stoloniferous root systems. They have approximately the same climatic and soil adaptations as redtop and are used for lawns and for putting greens on golf links, since they stand very close mowing. These grasses are of special importance on those soils where bluegrass does not thrive.

ORCHARD GRASS

Origin and History.—Orchard grass (*Dactylis glomerata*), the cock's foot grass of England, is a native of the Old World. It is native to most of Europe, nearly all of the northern half of Asia, the mountains of Algeria and the Canaries. It was cultivated in Virginia before 1760 and in this year was introduced into England. In Europe its cultivation began in the early part of the nineteenth century. It is now cultivated in practically all temperate regions.

FIG. 125.—Orchard grass (*Dactylis glomerata* Linnæus). (*U. S. Dept. Agr. Farmers' Bul.* 1254).

Description.—Orchard grass is a long-lived, perennial grass which forms dense circular bunches. It does not produce good sod, being a typical bunch grass, and it has no stolons. The name "cock's foot" comes from the characteristic shape of the inflorescence. The folded leaf blades and compressed sheaths are also characteristic.

The bunching habit of growth and the tendency for the stems to become woody soon after the blooming stage is reached may be considered objectionable features of orchard grass.

Adaptation.—Orchard grass is grown to some extent in practically every state in the Union but it reaches the greatest importance in Kentucky, southern Indiana, Tennessee, North Carolina, Virginia, West Virginia and Maryland.

The crop is strictly adapted to temperate regions but it will stand more heat than timothy and is more injured by cold. It starts growth earlier in the spring than most grasses and this early growth may account for some of the cold injury in the spring. Orchard grass is peculiarly well adapted for growing under shade; hence its name.

Orchard grass will grow on almost all kinds of soils but it thrives best on the heavier soils such as clays and clay loams. It requires somewhat more moisture than timothy for best growth but it will also make better growth during droughts than timothy.

Uses.—Orchard grass is used for both hay and pasture. It will produce a fair amount of hay on the thinner, dry uplands but the crop is woody if it is not cut at the proper time. It is used as a hay plant largely where timothy does not thrive. As a pasture grass, orchard grass serves an excellent purpose, especially in mixtures since the growth begins early in the spring and since a large amount of aftermath is ordinarily produced. The other plants in the mixture tend to thicken the sod between the bunches of orchard grass.

FIG. 126.—Kentucky bluegrass (*Poa pratensis* Linnæus). (*U. S. Dept. Agr. Farmers' Bul.* 1254).

KENTUCKY BLUEGRASS

Origin and History.—Kentucky bluegrass (*Poa pratensis*), also known as June grass, is not a native of North America but occurs over nearly all of Europe and the northern half of Asia and in the mountains of Algeria and Morocco. The first mention of it in the United States was made by William Penn in 1685. The grass has spread rapidly in certain regions in this country.

Description.—Kentucky bluegrass is a perennial having creeping underground stems which bear tufts at the tips. It spreads rapidly by means of the rhizomes and forms a permanent sod. The panicles are spreading as compared with Canada bluegrass and purplish in color, while the stems are rather fine and cylindrical. The leaves are green and V-shaped in cross-sections; the leaf tips resemble the bow of a boat in shape. Kentucky bluegrass should always be seeded in mixtures containing plants which reach full development fairly early, as bluegrass usually requires two or three years before a good dense sod is secured.

Adaptation.—Kentucky bluegrass thrives best in the cooler sections of the countries. It can be grown farther south than timothy but it is

not adapted to the Gulf states. It is the best known grass in America. with the probable exception of timothy.

Kentucky bluegrass is adapted to temperate regions of relatively high humidity but under irrigation it will grow under arid conditions. It is very cold resistant and will start growth during the warmer periods in the winter season. It makes an excellent early spring and fall growth but during the latter part of the summer the plants languish, even when moisture is abundant. However, if sufficient moisture is present, the growth quickly revives in the fall. The crop grows only fairly well under shade.

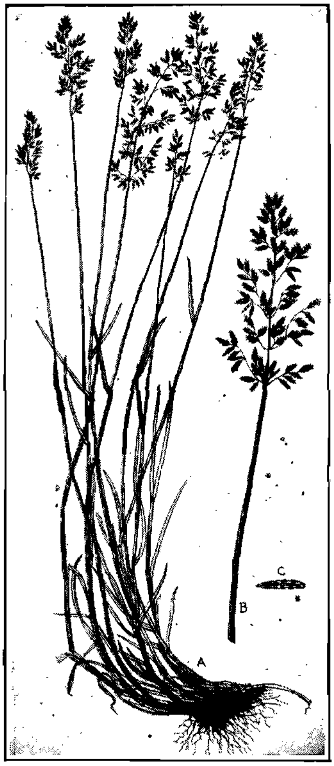

Fig. 127.—Canada bluegrass (*Poa compressa* Linnæus). (*U. S. Dept. Agr. Farmers' Bul. 1254*).

Kentucky bluegrass thrives best in the well-drained heavier types of soil, rich in organic matter and plant nutrients. It was once thought that, on account of the lime present, this grass was especially adapted for limestone regions. However, the present indications are that the excellent growth in such regions is rather a result of the general richness of the soil than of the lime content. The grass is not so well adapted to dry or wet soils as redtop.

Uses.—The main use of Kentucky bluegrass is for pastures and lawns. Most of the bluegrass pastures have arisen spontaneously but they can be secured much quicker by sowing bluegrass seed in the mixture. The beauty of bluegrass lawns is well known.

CANADA BLUEGRASS

Origin and History.—Canada bluegrass (*Poa compressa*) was introduced at an early date into the United States from Europe. It was found by Michaux in Quebec about 1792 and by Richardson along the upper Saskatchewan in 1823. Its dissemination in America has been very rapid.

Canada Bluegrass Compared with Kentucky Bluegrass.—These grasses may be distinguished from each other by several characteristics. Canada bluegrass has a compressed stem and more compact panicle than Kentucky bluegrass. It is less productive than Kentucky bluegrass and it does not form so dense a sod. The herbage is a dark bluish-green in color and the stems bend at the nodes. Kentucky bluegrass has cylindrical, straight stems, forms a dense sod and the herbage is a true green in color.

In adaptation, Canada bluegrass has about the same climatic requirements as Kentucky bluegrass but it is more resistant to summer heat and to drought. It is better adapted to poor and dry soils than Kentucky bluegrass but less adapted to moist or wet soils.

Like Kentucky bluegrass, Canada bluegrass may be used for both pasture and lawns. It has a somewhat higher nutritive value than Kentucky bluegrass. Where Kentucky bluegrass does well, it is preferable to Canada bluegrass when all things are considered.

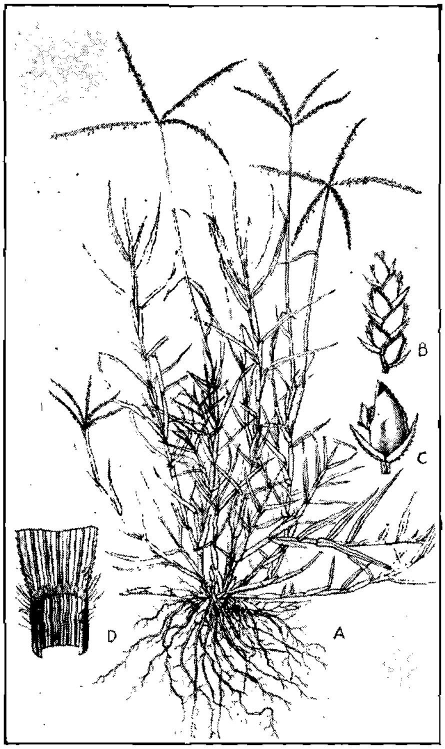

Fig. 128.—Bermuda grass (*Cynodon dactylon* (Linnæus) Persoon; *Capriola dactylon* (Linnæus) Kuntze). *A*, Entire plant, showing habit; *B*, part of a flowering branch, showing the arrangement of the spikelets; *C*, spikelet much enlarged; *D*, junction of blade and sheath, showing the character of the ligule. (*U. S. Dept. Agr. Farmers' Bul.* 1254).

BERMUDA GRASS

Origin and History.—Bermuda grass (*Cynodon dactylon*) is a native of India and probably of other parts of the Old World in tropical and subtropical regions. It is not known when it was introduced into the United States but in 1807 it was an important grass in the southern states.

Description.—Bermuda grass is a long-lived perennial spreading by runners or by rootstocks or by both, and by seeds. The runners usually vary in length from a few inches to 3 or 4 feet, but at times much greater

length is obtained. The runners, which creep over the surface of the ground, often root at the nodes at which places aërial stems are also produced. The stout rootstocks may be as large as a pencil and aid in making the plants very vigorous. By the growth of these organs a single plant may cover several square yards in area. The stems of the plants are very leafy; and since several nodes are frequently very close together, the stems often appear to have several leaves from the same node. The leaves are flat and spreading and may be distinguished from those of other grasses by the ligule, which is made up of a circle of white hairs.

Varieties.—There exists much variation in Bermuda grass. There are several varieties: the common Bermuda, St. Lucie grass, Brazil Giant Bermuda and Florida Giant Bermuda. St. Lucie grass is identical in appearance to common Bermuda but lacks rootstocks and seldom lives through the winter north of Florida. It is rather dwarfish and is one of the best varieties for lawns and dooryards. Brazil Giant Bermuda is the most rank-growing kind and produces long runners, but it rarely produces seeds and has few or no underground rootstocks. The Florida Giant Bermuda grass is very similar to the Brazilian sort but has shorter runners, produces seed heads profusely and has pale green foliage in contrast with the rich blue-green herbage of the Brazil.

Adaptation.—Bermuda grass fills about the same place in the South as Kentucky bluegrass does in the North. It is the most important perennial grass in the southern states

Bermuda grass requires warm weather during the growing season and will bear intense heat without injury. However, it is not resistant to cold and rarely persists where the temperature remains below zero for a great length of time, although the rootstocks will withstand for a short time somewhat colder air temperature. The leaves turn brown as a result of the first fall frost and growth does not start in the spring until danger of frost is over. Bermuda grass will not stand shading well and this fact is taken advantage of in eradication.

The grass will grow on all types of soil but it thrives best on well-drained, rich, moist, bottom lands. It apparently does not respond to applications of lime.

Uses.—Bermuda grass is used for hay, pasture, lawns and soil binding; it stands clipping well and tramping does not injure it. The grass is difficult to eradicate and for this reason it should not be sown in fields which are to be cultivated.

PERENNIAL RYE GRASS

Origin and History.—Perennial rye grass (*Lolium perenne*) was the first grass to be cultivated to any large extent. It grows naturally in temperate Asia and southern Europe and in North Africa. The grass was early introduced into the United States.

Description.—Perennial rye grass is a short-lived, rapid growing, tufted perennial which ordinarily attains a height of $1\frac{1}{2}$ to 2 feet. On poorer soils the grass lives only 2 years; and frequently, when seeded in hay mixtures, perennial rye grass will disappear after the first year as a result of shading by taller plants. Since the under surfaces of the leaves are bright and glossy, the grass has a noticeable appearance in the spring. Italian rye grass also has this appearance.

Perennial rye grass may be distinguished from Italian rye grass by the folded instead of convolute leaves and by the awnless lemmas.

Adaptation.—Perennial rye grass is best adapted to regions with cool, moist climates having mild winters. It grows to some extent during the winter and is not very resistant to cold. It is similar to orchard grass in cold resistance.

The plants are best suited to rich, moist, well-drained soils. Hot dry spells frequently kill or greatly retard the growth of the crop on uplands. The lack of drought resistance is a serious handicap.

Uses.—Perennial rye grass makes rapid germination and growth and for this reason it is frequently included in pasture and lawn mixtures. It serves excellently as a temporary covering, while the more valuable and permanent plants are being established. It is also used to sow on Bermuda pastures in the South for winter grazing.

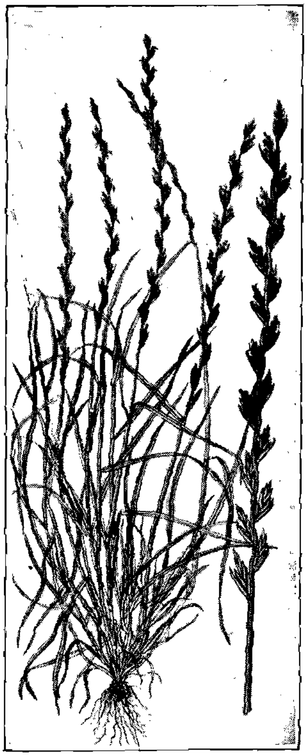

FIG. 129.—Perennial rye grass (*Lolium perenne* Linnæus). (*U. S. Dept. Agr. Farmers' Bul.* 1254).

ITALIAN RYE GRASS

Origin and History.—Italian rye grass (*Lolium multiflorum*) is a native of southern Europe, northern Africa and Asia Minor. It is an important grass in Europe but not of great importance in this country.

Description.—Italian rye grass is not an annual but under ordinary conditions it lives for only one year. Under favorable conditions the life is 2 years. It grows rapidly, forming tufts, and the plants reach a height of $1\frac{1}{2}$ to 3 feet. The lemmas are awned and the leaves are inrolled at first.

Adaptation.—Italian rye grass is best adapted to regions with moist, mild climates, but it does best in the Atlantic and Pacific Coast states.

It will grow on a great variety of soils but does best on rich loams with abundance of moisture. The crop does well under irrigation.

Uses.—On account of the quick germination and growth, Italian rye grass is often used in pasture and lawn mixtures. In the South the seeds are sown on Bermuda grass sod to furnish winter grazing. Italian rye grass is sometimes used for an annual hay plant but the yields in this country are not nearly so good as those obtained in Europe.

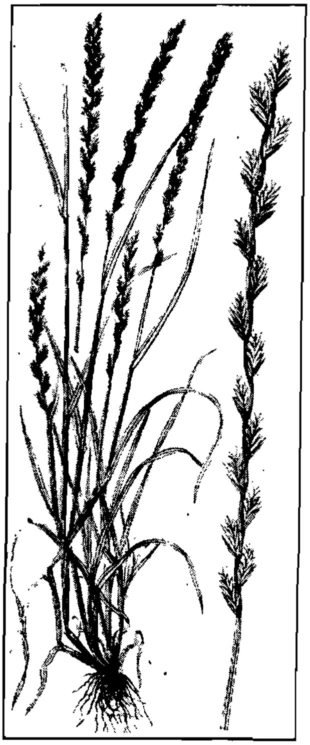

Fig. 130.—Italian rye grass (*Lolium multiflorum* Lamarck; *Lolium italicum* R. Brown). (*U. S. Dept. Agr. Farmers' Bul.* 1254).

BROME GRASS

Origin and History.—Brome grass (*Bromus inermis*), also called smooth brome and awnless brome, is native to eastern Europe, Siberia and China. It was introduced into the United States about 1880.

Description.—Brome grass is a long-lived, drought-resistant perennial with many underground rootstocks. Each plant may reach a diameter of a foot or more. Under favorable conditions the culms attain a height of 5 feet and many usually arise from one plant. In a few years' time a dense sod is formed. The roots of 1-year old plants have been found to reach a depth of 4 feet and those of 2-year old plants a depth of 5½ feet

Adaptation.—Brome grass is especially adapted to regions of low rainfall and moderate temperature during the growing season. It withstands cold exceedingly well and does especially well in the Dakotas and Canada. High humidity and high temperatures during the growing season are both detrimental to the best growth of this grass. The plants thrive best on loams and clay loams but even on sandy soils they do well, and the drought resistance of the grass is remarkable.

Uses.—Brome grass is used for both pasture and hay. However, it is peculiarly adapted for pasture purposes.

FESCUES

There are a number of fescues and they are important in limited areas of the country. It is scarcely feasible to do more than mention a few of them here. Meadow fescue (*Festuca elatior*) is a long-lived, tufted,

deep-rooted perennial, adapted to the timothy section of the country. It is used for both pasture and hay purposes. Sheep's fescue (*Festuca ovina*) is a long-lived, bunch, perennial grass. It is adapted to practically the same climatic conditions as Kentucky bluegrass and should be sown on land that will not produce better grasses, as it does reasonably well on such soils. Red fescue (*Festuca rubra*) is a long-lived, perennial grass possessing underground stems; it does not grow in tufts. It is used mainly for lawns, especially on sandy or gravelly soils and on soils that are well shaded. It is also used on golf courses but this use is diminishing.

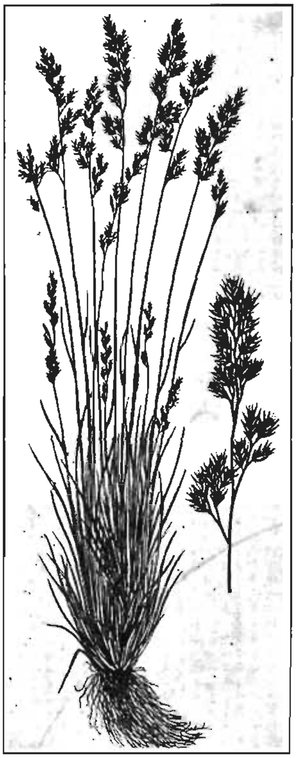

FIG. 131.—Sheep's fescue (*Festuca ovina* Linnæus). (*U. S. Dept. Agr. Farmers' Bul.* 1254).

TALL MEADOW OAT GRASS

Origin and History.—Tall meadow oat grass (*Arrhenatherum elatius*), also known as tall oat grass, meadow oat grass, evergreen grass and false oat grass, is native to southern Europe and northern Africa but extends into Persia. It was cultivated in Europe about the middle of the eighteenth century and in Massachusetts and South Carolina in the early part of the nineteenth century. Tall meadow oat grass is a standard grass in certain regions of Europe and is rather widely grown over the United States but it is not of special importance in any section.

Description.—Tall meadow oat grass is a hardy perennial growing to a height of from 30 to 60 inches and producing large tufts or bunches. The seeds, which somewhat resemble those of cultivated oats, are borne in panicles. The spikelets bear two florets and the lower has a long, twisted, elbowed awn. Tall meadow oat grass may be used either for hay or pasture. It stands pasturing well and furnishes much grazing, as it comes early in the spring and remains green until late fall. The grass has a peculiar taste but apparently this is not a serious drawback as the grass is readily eaten by live stock.

There is a variety of tall meadow oat grass known as *tuberosa* which bears small bulbs at the base resembling a string of small onions and is sometimes called "onion couch." This variety yields less than the ordinary tall meadow oat grass.

Adaptation.—Tall meadow oat grass in its adaptation resembles orchard grass so far as climatic conditions are concerned. It will not

ndure as much cold as timothy but it stands more summer heat. Tall neadow oat grass prefers well-drained soils and is especially adapted o light sandy or gravelly land; probably no other perennial grass does is well on poor land. However, it thrives on rich land and responds to he use of fertilizers. Tall meadow oat grass is very drought resistant, eing surpassed in this respect only by western wheat grass and *Bromus nermis.* It does not grow well in shade.

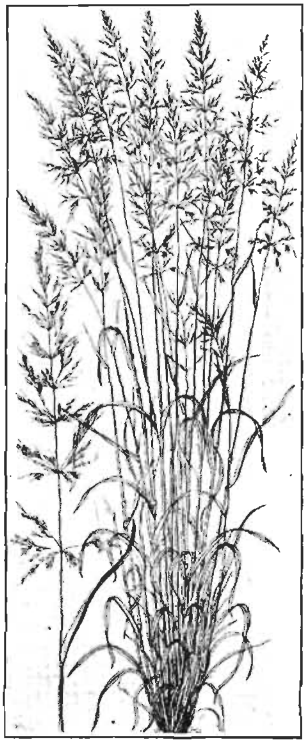

FIG. 132.

FIG. 133.

FIG. 132.—Tall meadow oat-grass (*Arrhenatherum elatius* (Linnæus) Beauvois). (*U. S. Dept. Agr. Farmers' Bul.* 1254).

FIG. 133.—Carpet grass (*Axonopus compressus* (Swartz) Schlechtendahl). *A*, Entire lant; *B*, junction of blade and sheath, showing the structure of the ligule; *C*, branch with ve spikelets, enlarged. (*U. S. Dept. Agr. Farmers' Bul.* 1254).

Uses.—Tall meadow oat grass is most useful as a hay grass. It is isually seeded in mixtures with such plants as orchard grass and alsike lover. Rapidly growing plants, as Italian and perennial rye grasses, hould not be included as the tall meadow oat grass seedlings will likely e injured by shading. The use of tall meadow oat grass is limited by he poor seeding habit of the plants and the low vitality of the seeds.

SOUTHERN GRASSES

Much interest is now being manifested in the southern states in regard to securing adapted grasses as the preliminary step in fostering the production of more and better live stock in that area. Among the

FIG. 134.—Dallis grass (*Paspalum dilatatum* Poiret). (*U. S. Dept. Agr. Farmers' Bul.* 1254).

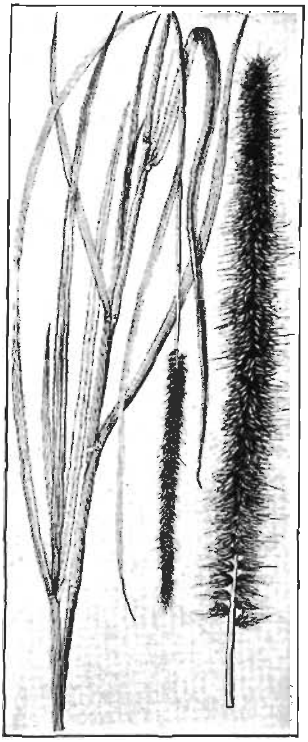

FIG. 135.—Napier grass (*Pennisetum purpureum* Schumacher). (*U. S. Dept. Agr. Farmers' Bul.* 1254).

grasses that have proved of value are Bermuda grass (*Cynodon dactylon*), carpet grass (*Axonopus compressus*) and paspalum or Dallis grass (*Paspalum dilatatum*). Other grasses of merit are Napier (*Pennisetum purpureum*), Para (*Panicum barbinode*) and Rhodes grass (*Chloris gayana*).

Certain Characteristics of Grasses.—Some of the characteristics of the most common grasses are given in Table CXIII.

TABLE CXIII.—SHOWING CERTAIN CHARACTERISTICS OF GRASSES

Kind of grass	Time required for full development, yr.	Life of good stand, yr.	Tolerance of wet or dry soils	Tolerance of acid soils	Type of growth	Uses	Weight per bu., lb.	Rate of seeding alone, lb. per acre
Timothy	1	3–10	Not tolerant	Not tolerant	Semi-bunch	Hay	42–60	15
Redtop	1	Fairly permanent	Tolerant	Tolerant	Sod	Hay and pasture	36	10
Orchard	2	5–10	Tolerant	Tolerant	Bunch	Hay and pasture	14	25
Kentucky bluegrass.	2–3	Permanent	Not tolerant	Not tolerant	Sod	Pasture and lawns	14	14
Canada bluegrass.	2–3	Permanent	Tolerant of dry	Tolerant	Sod	Pasture	14–24	14–24
Bermuda	3–4	Permanent	Tolerant of dry	Tolerant	Sod	Pasture and hay	35–36	5
Perennial rye grass	1	1–2	Tolerant of wet	Tolerant	Semi-bunch	Pasture, lawns and hay	20	30
Italian rye grass	1	1	Tolerant of wet	Tolerant	Semi-bunch	Pasture, lawns and hay	24	30
Brome	2	Permanent	Tolerant of dry	Not tolerant	Sod	Pasture and hay	14	20
Tall meadow oat grass.	2	5	Tolerant of dry	Tolerant	Bunch	Hay and pasture	10–16	40

CHAPTER XLII

CLOVERS

The true clovers belong to the genus *Trifolium.* Therefore Japan clover, sweet clover and the bur clovers are, strictly speaking, not true clovers.

General Description.—The true clovers are annual, biennial or perennial herbs with palmately trifoliate leaves. The inflorescence is a dense spike or head with flowers which vary in color with the species. The seeds, which are usually more or less kidney-shaped, are borne in small, mostly one-seeded pods which open circularly.

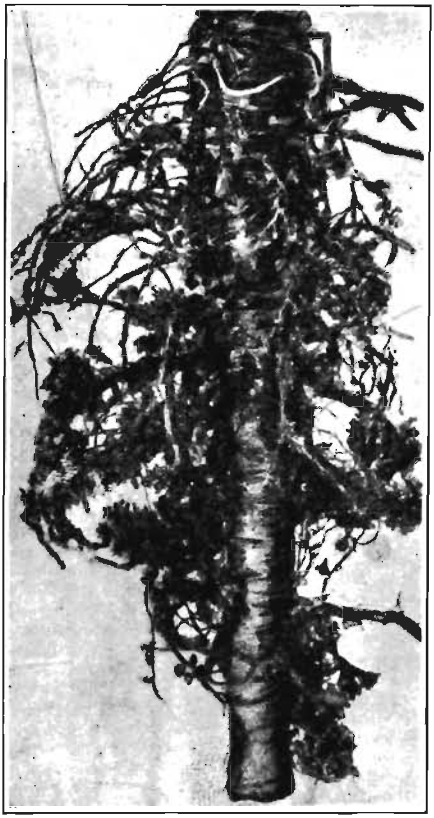

Fig. 136.—A wonderful development of nodules on sweet clover.

The members of this group have well-defined tap roots; these go comparatively deep into the soil and have numerous lateral roots which spread in all directions through the surrounding soil mass. The clovers are rich in nitrogenous materials and are highly prized as feed for live stock. They are also valuable plants for soil improvement purposes since they, in common with other legumes, have the power of utilizing atmospheric nitrogen through association with the bacteria which are found on their roots. When clovers are turned under, they decay rapidly and soon become incorporated with the soil. The clovers are so highly valued by farmers that in many sections their presence on farms is considered indicative of prosperous conditions.

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RED CLOVER

Origin and History.—Red clover (*Trifolium pratense*) was not cultivated in ancient times except apparently in Media and adjacent regions. It is a native of Europe, Algiers, Asia Minor, Turkestan, southern Siberia and the Himalayas. It is known to have been cultivated in Spain and Italy as early as the fifteenth and sixteenth centuries and it reached England in 1633 through Flanders. The first published mention of it in the United States was in 1747 by Jared Eliot. The spread has been rapid in the United States.

FIG. 137.—Red clover (*Trifolium pratense*). (*U. S. Dept. Agr., Forage Crop Investigations*).

Description.—The red clover plant is usually biennial, but better yields are secured the first year after the seeding year than in the second year. The plants, if allowed to produce seeds, usually die, even though they may not be 2 years old. Often in good seasons the plants have a tendency to bloom late in the fall. It is a common practice to graze or mow off the crop to prevent production of seeds at this time.

The plant is herbaceous and consists of many leafy stems arising from a crown. The flowers, which are generally rose-pink and frequently numerous, are borne in compact clusters or heads at the tips of the branches. Each leaf consists of three oblong leaflets and usually has a pale spot in the center. The roots are usually deep, much branched, and generally well supplied with nodules. Hays (1888) at the Minnesota Experiment Station found that a red clover plant at the age of 5 months had a tap root which descended to a depth of 5½ feet. The secondary roots were still deeper. However, there was greatest root development in the surface 1½ feet of soil.

Adaptation.—The red clover plant is grown most extensively in the north central and northeastern portions of the United States.

Red clover is best suited to regions with abundant rainfall and without extreme summer and winter temperatures; although, it is grown in Maine, Minnesota and parts of Canada. It is quite resistant to cold and certain strains seem more resistant than others. However, some strains, such as the Italian, are especially susceptible to cold injury. The crop is not suited to shady places.

Red clover will grow in almost any kind of soil on which corn will grow. It does best on the heavier kinds of soils which are deep, well-drained, productive and rich in lime, and which have a rather high content of organic matter. The moisture conditions of the soil are important. The crop will not thrive on open soils which tend to dry out rapidly nor will it do well on poorly drained soils.

Varieties of Red Clover.—There are a number of varieties of red clover and each has more or less of a special adaptation. The two main varieties in the United States are medium red clover (*Trifolium pratense*) and mammoth or sapling clover (*Trifolium pratense perrene*). The latter blooms about 2 weeks later than the former, the stems are usually solid as compared with the hollow stems of *Trifolium pratense* and it will produce either a crop of hay or a crop of seed in the same season, while medium red clover may produce both. Since mammoth clover blossoms with timothy, it is usually better for growing for hay with timothy than is medium red clover.

Uses.—Red clover is the main leguminous forage crop in the region to which it is adapted. It is used primarily for hay purposes and is sown extensively with timothy. Red clover is also a good pasture plant and is used to some extent for silage and soiling purposes. It fits well into many crop rotations and the effect of the crop on the yields of subsequent crops in the rotation is generally very beneficial.

ALSIKE CLOVER

Origin and History.—Alsike clover (*Trifolium hybridum*) is so named from the locality in Sweden from which the plant came to England. It

is a native of temperate Europe and Asia and occurs in Algiers. Alsike clover has been cultivated in its native home since the tenth century. However, it was not introduced into England until 1834 and was not brought into the United States until 1854. It was thought at one time to be a hybrid between red and white clover, but is now recognized as a separate species.

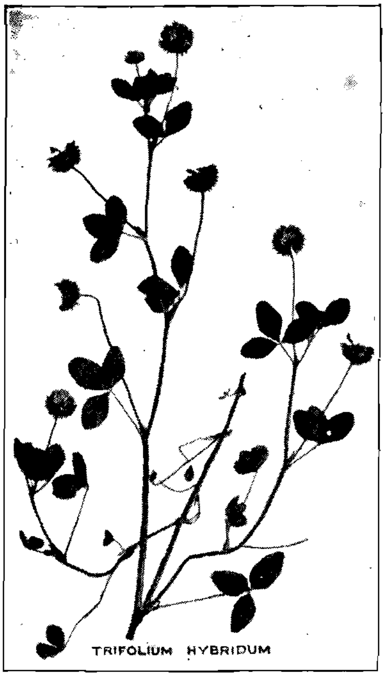

Fig. 138.—Alsike clover (*Trifolium hybridum*, L.). (*U. S. Dept. Agr., Forage Crop Investigations*).

Description.—Alsike clover is a perennial plant and the smooth leafy stems arise from a crown. The stems are erect or ascending when crowded; but when the plants are isolated, the habit of growth is spreading. Each leaf is composed of three leaflets and the heads of the flowers are partly pink and partly white in color. Sometimes the flowers of some heads are all white and again all pink. Alsike clover is more leafy than red clover and differs in habit of growth. In red clover the main axis terminates in a flower and growth is limited; in alsike clover the main axis continues to grow. In either clover, new branches may arise from the leaf axils, but only in the case of alsike clover does the main axis of the plant continue to grow. Under favorable conditions the stems reach a length of 2½ to 5 feet, but ordinarily about 2 feet.

Hays (1888) at the Minnesota Experiment Station reports the tap root of a 1-month old plant to be 9½ inches long; at two months he reports a length of more than 2 feet. The tap root does not remain prominent, as the secondary roots become comparatively large. At the same age the root development of alsike clover is greater than that of red clover.

Adaptation.—In the United States alsike clover is generally grown north of the Ohio and the Potomac rivers, and as far west as the Dakota-Minnesota boundary. The crop is also grown in Idaho and on the coast of Washington and Oregon, but is not extensively grown in the South, being limited largely to Virginia, Kentucky, Tennessee and Missouri.

Alsike clover requires a cool climate with abundant moisture, as it is very cold resistant, being more so than red clover. Although drought greatly reduces the yield of alsike clover, it is probably as resistant to

dry weather as red clover. The plants do well on nearly all kinds of soils, provided there is abundant moisture present, but the most luxuriant growth is made on the heavier soils. Alsike clover will grow well on wet lands and on lands which will not produce red clover on account of "clover failure." The crop responds to lime applications, but it is not so sensitive to soil acidity as red clover.

Uses.—The production of alsike clover is on the increase. It is used largely where red clover yields are decreasing. It may be said that where red clover does well, alsike is not generally used, because the former gives larger yields. Alsike clover makes an excellent hay. However, it is generally not seeded alone for hay, but is usually seeded with timothy or with timothy and red clover. The plants are especially suited for pasture mixtures.

WHITE CLOVER

Origin and History.—White clover (*Trifolium repens*), also known as Dutch clover, is native to temperate Europe and Asia, and occurs in the Azores. The plant was apparently first cultivated in Holland. The presence of white clover in the United States was mentioned by Jared Eliot in his writings of 1747 and by Strickland in 1794 in an account of his travels in the United States. In this country white clover spreads rapidly in certain sections, usually in association with Kentucky bluegrass.

Description.—White clover is a long-lived, shallow-rooted perennial. It differs greatly from red and alsike clovers in two ways: it has a prostrate, creeping habit and the stems root at nearly every node. The plants spread rapidly, frequently form a dense turf, and are seldom injured by mowing and grazing.

Hays (1888) at the Minnesota Experiment Station found a 1-month old plant having a tap root 4½ inches long and many branch roots. At 2 months the tap root was 2 feet long and roots were forming at the nodes of the creeping branches. The tap root apparently dies in one or two years.

A tall-growing variety of white clover is the Ladino clover (*Trifolium repens latum*). It is said to be much less cold resistant than ordinary white clover.

Adaptation.—White clover is widely grown, occurring in all parts of the country. It thrives best under cool, moist climates, and in the South the greatest growth is made in cooler seasons of the growing period. White clover will grow on almost any kind of soil, provided sufficient moisture is present, but the best growth is made on the heavier, well-drained soils that are rich in humus. It does well in shady places.

Uses.—White clover is a pasture plant; and in the seeding of pasture mixtures, a small amount of seed of this plant is usually included. How-

ever, in some sections of the country white clover and bluegrass appear naturally as soon as the land is cleared.

CRIMSON CLOVER

Origin and History.—Crimson clover (*Trifolium incarnatum*), also known as scarlet, incarnate and German clover, is a native of Europe and it is cultivated in Italy, France, Spain, Germany, Austria and Great Britain as a forage and green manuring crop. The wild plant has yellow flowers; one form has rose-colored flowers and is shorter, less vigorous and more hairy than the cultivated form. It was introduced into the United States in 1818 and widely distributed by the United States Patent Office in 1855.

Description.—Crimson clover is a winter annual; that is, it usually makes its early growth in the fall, passes the winter in a dormant but green state, makes a rapid early spring growth, matures and dies before summer. The stems branch from the base and are nearly erect when the plants are crowded, but may be somewhat spreading in the case of isolated plants. Each stem is terminated by a spike or head, which is usually a brilliant crimson when in bloom. The vegetative portions of the plant are hairy.

Adaptation.—Crimson clover is best suited to the sandy soils of the Atlantic Coastal Plain. The crop does not thrive under conditions of extreme cold or heat, but grows best in those sections having a long period of relatively mild, moist weather. It does not survive the winter ordinarily, north of the latitude of southern Pennsylvania; and in the South the dry hot weather in the fall and spring is very detrimental. It grows well in the shade.

Crimson clover will grow well on almost all soils, provided they are well drained, productive, supplied with organic matter and inoculated with the proper bacteria. The crop responds to applications of lime, but it is less sensitive to soil acidity than some of the other clovers. Crimson clover can be grown successfully on poor soils by proper treatment as regards liming, inoculating, fertilizing and so on.

Uses.—Crimson clover may be used for a number of purposes: it may be used for hay, soiling and pasture. However, the crop is chiefly grown as a cover crop and as a green manure crop.

SWEET CLOVER

Origin and History.—Sweet clover (*Melilotus alba*) is a native of western Asia and has been known for about 2,000 years in the region of the Mediterranean. The white sweet clover was introduced into the United States in 1738, but only in the last 25 to 30 years has the crop been grown extensively.

Description.—There are both biennial and annual forms. The stems vary in height from 6 to 12 feet and bear numerous sweet-scented flowers in narrow, erect racemes. The seeds are borne singly in reticulate pods. All portions of the plant contain a bitter-tasting compound known as "cumarin," which has a sweet, vanilla-like odor.

Adaptation.—Sweet clover has a wide range of climatic adaptation and it can be grown in nearly all parts of the country. It does equally well under humid and under dry conditions; and as long as moisture is abundant, neither the hot climate of the South nor the cold weather of the North apparently injures the crop.

Sweet clover also has a wide range of adaptation as far as the soil is concerned. It can be grown on all kinds of soils, but it is especially important to have sufficient lime present. The plants have well-developed root systems, and can apparently withstand drought nearly as well as alfalfa. On wet or poorly drained soils the crop thrives better than red clover or alfalfa.

Uses.—The crop has many uses. It may be used for pasture, hay, silage, soiling, or for soil improvement; it may also be used as a honey plant.

Related Species.—There are four kinds of sweet clover grown in the United States: biennial white sweet clover (*Melilotus alba*), biennial yellow sweet clover (*Melilotus officinalis*), annual yellow sweet clover (*Melilotus indica*) and annual white sweet clover or Hubam (*Melilotus alba* var. *annua*).

LESPEDEZA

Origin and History.—Lespedeza (*Lespedeza striata*) is also commonly known by the name "Japan clover." The plant is a native of eastern Asia, being found in Japan, Korea, Manchuria, Mongolia and China. Lespedeza was introduced into the United States before 1846. The first authentic record of the plant in this country dates back to August, 1846, when Thomas C. Porter, Monticello, Georgia, discovered a specimen which is still preserved.

Description.—Lespedeza is a summer annual, which grows to a height of 4 to 6 inches under ordinary conditions; under favorable conditions, however, as on alluvial bottom land, it reaches a height of 15 to 24 inches.

In thin stands the plants are much branched and spreading or prostrate, but in thick stands the branching is less and the stems are more or less erect. The growth starts rather late in the spring, the small purple blossoms appear in the late summer and the seeds are matured in the fall. Under favorable circumstances the crop readily reseeds itself, and for this reason a stand is maintained from year to year by natural seeding.

The roots are not deep. Dodson and others (1911), however, at the Louisiana Experiment Station, estimated that the stubble and the roots to a depth of 12 inches constitute about one-third of the weight of the hay removed. Essary (1921) in Tennessee found that the roots penetrated to a depth of 24 inches even in hard clay soils.

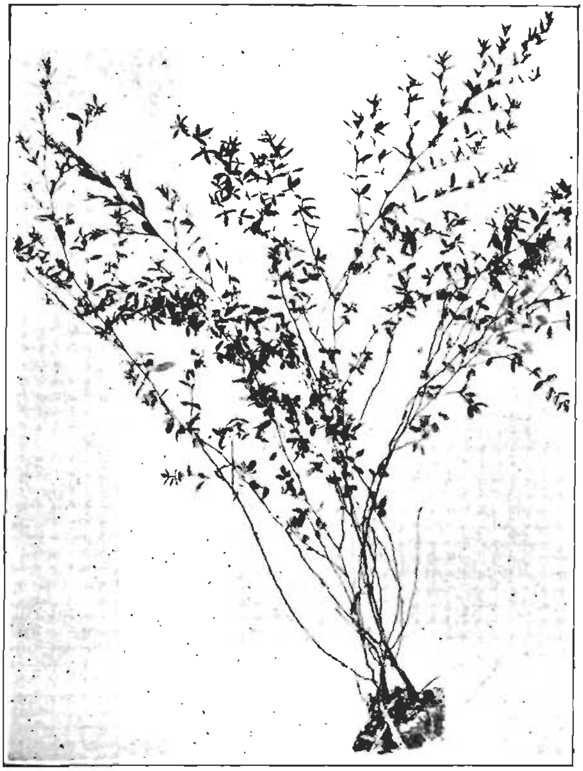

FIG. 139.—Japan clover (*Lespedeza striata*). (*U. S. Dept. Agr., Forage Crop Investigations*).

Essary (1921) at the Tennessee Experiment Station, has selected and propagated three new varieties of lespedeza. One variety is especially suited for hay, another does well for pasture and the third is early maturing. The United States Department of Agriculture has also secured a Korean lespedeza which produces seed abundantly in the cooler and higher altitudes.

Adaptation.—Lespedeza occurs in more or less abundance from central New Jersey westward to central Kansas and southward to the Gulf of Mexico. Over most of this area the plants grow only tall enough for pasturage, but in the lower Mississippi Valley the crop frequently becomes sufficiently high for mowing as hay. The crop was widely distributed by the movement of cavalry during the Civil War.

Lespedeza thrives in hot weather and seldom begins growth in the spring until warm weather. Since it is sensitive to frost, it does not make early spring or late fall growth.

The crop will grow on all kinds of soils as long as they are well drained near the surface. However, on the richer lands the yield is higher. Essary (1921) found in Tennessee that liming was very profitable in growing lespedeza. It should be stated further that lespedeza is well suited for pasture on poor or "worn out" lands.

Uses.—Lespedeza is used extensively for pasture and in certain sections of the South it is important as a hay crop, frequently yielding 1 to 3 tons of field-cured hay per acre. It is well adapted to sowing in mixtures with such grasses as Bermuda, redtop and Johnson.

BUR CLOVERS

Kinds of Bur Clover.—There are about 35 species of bur clover, but the only types of importance cultivated in this country are the two following: spotted or southern bur clover (*Medicago arabica*) and toothed or California bur clover (*Medicago hispida denticulata*). Both of these species are natives of the Mediterranean region and were early introduced into the United States.

The spotted bur clover can be distinguished from the California species by the purple spot on the center of each leaflet. Also, the pods of the former contain two to eight seeds, while those of the latter usually contain three and sometimes five seeds.

Description.—The two species under consideration are annuals, having small yellow flowers in clusters of five to ten, and the seeds are borne in coiled pods which are usually beset with spines; hence comes the name "bur." The plants ordinarily branch profusely from the crown and usually have from ten to twenty or more spreading or decumbent branches. The branches are from 6 to 30 inches long, and well-developed plants frequently contain as many as 1,000 pods. The roots are fibrous and are comparatively shallow. Under favorable conditions these clovers reseed themselves naturally each year.

Adaptations.—Agriculturally, the bur clovers are of importance only where the winters are mild. The spotted or southern bur clover is limited particularly to the cotton belt and the toothed or California bur clover is found especially on the Pacific Coast west of the Cascade and Sierra Nevada Mountain Ranges. However, both species are found in each region.

The bur clovers are winter annuals and are best adapted to regions with mild, moist winters. Toothed bur clover seems to be less cold resistant than southern bur clover.

These clovers are best suited to loam but they will grow on all kinds of soils. Usually, moist, well-drained soils are preferred but frequently

the California bur clover does well on poorly drained soils. Lime is not necessary for the growth of these plants but they respond to its use.

Uses.—The bur clovers serve a very good purpose as a cover and green manure crop. The crop is used to a great extent as a pasture, especially for hogs, cattle and sheep, and is very satisfactory for seeding with Bermuda grass. Under favorable conditions, bur clover becomes tall enough to be used as hay. Cauthen (1912), at the Alabama Experiment Station, reports a yield of 3,493 pounds of bur clover hay per acre.

Certain Characteristics of Clovers.—Some of the characteristics of the most common clovers are given in Table CXIV.

TABLE CXIV.—SHOWING CERTAIN CHARACTERISTICS OF CLOVERS

Kind of clover	Time required for full development, yr.	Life of good stand, yr.	Tolerance of wet or dry soils	Tolerance of acid soils	Type of growth	Uses	Weight per bu., lb.	Rate of seeding alone, lb. per acre
Red	1	Biennial	Not tolerant	Not tolerant	Erect	Hay and pasture	60	12
Alsike	1	2–5	Tolerant of wet	Tolerant	Spreading	Hay and pasture	60	10
White	2–5	Fairly permanent	Fairly tolerant	Tolerant	Prostrate	Pasture	60	8
Crimson	1	Winter annual	Not tolerant	Fairly tolerant	Erect	Green manure and pasture,	60	15
Sweet (biennial)	1	Biennial	Not tolerant	Not tolerant	Erect	Pasture green manure and hay	Hulled 60 Unhulled 32	15 30
Lespedeza	1	Summer annual	Not tolerant of wet	Tolerant	Spreading	Pasture	25	25
Bur	1	Winter annual	Not tolerant of wet	Tolerant	Prostrate	Green manure and pasture	Hulled 60 Unhulled 10	15 30

CHAPTER XLIII

ALFALFA (Medicago sativa)

Alfalfa is the second most important forage crop in the United States at the present time, being exceeded in tonnage only by timothy and clover. It thrives best in the irrigated sections of the West and it does well under favorable conditions on the rich soils of the East. The crop does best on soils which are abundantly supplied with lime and the hay can be most

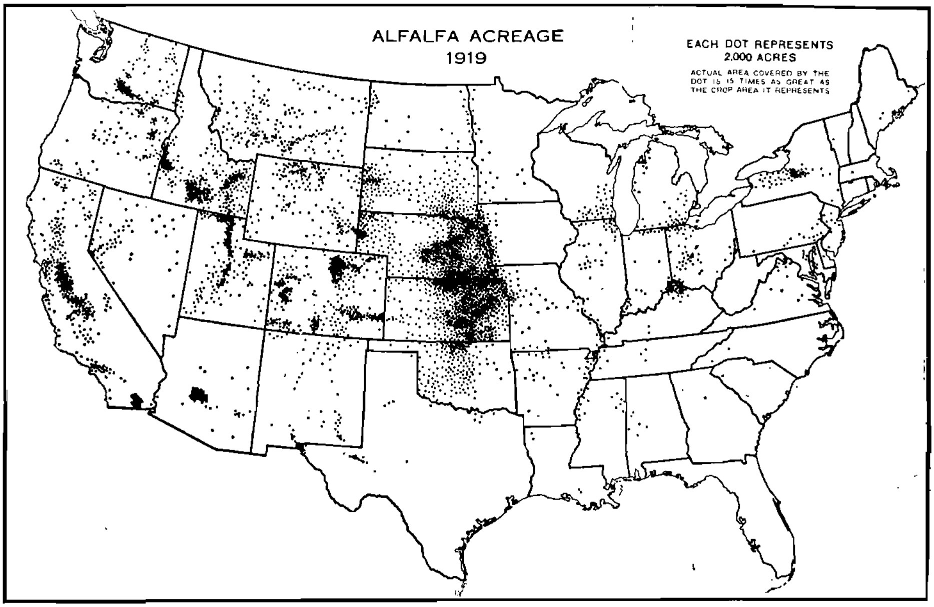

Fig. 140.—Alfalfa demands soils that are not acid, and it is most easily cured in a climate that is not rainy during the summer. Consequently, it thrives best in the western states, where it is grown mostly under irrigation, and fairly well in the limestone sections of the East, where its culture is increasing rapidly. This increase has been notable in the slightly sub-humid section of eastern Kansas and Nebraska, where the acreage has increased over sixfold in the past 20 years. Alfalfa replaces wild hay in this area as the major hay crop. Seven-eighths of the alfalfa acreage is west of the Missouri River. (*U. S. Dept. Agr. Yearbook*, 1921).

easily cured in a climate where rain is not abundant during the summer season. The climatic and soil requirements of alfalfa, especially the former, are very important in the production of the crop.

Production in the United States.—Figure 140 shows the acreage of alfalfa in the United States in 1919.

In 1919 the five states, Kansas, California, Nebraska, Colorado and Idaho, grew 10,640,429 tons. or 56.4 per cent of the entire crop of the country.

Historical.—Alfalfa was known to the Greeks and Romans. It was introduced into Greece from Media about 470 B.C. The crop is probably a native of Media or Persia as the wild alfalfa plants of that region closely resemble the cultivated strains. The crop was carried to Spain from Italy and introduced into Mexico from Spain and thence to Chili. From the latter country the crop was brought to California about the middle of the nineteenth century.

It is interesting to find that although alfalfa was introduced into the eastern part of the United States in the early part of the nineteenth century, about 1820 in New York, the rapid development of the crop was in the West. The crop is more adapted to the conditions existing in the West than to those in the East, and the rapid spread of the crop in the United States dates from the later introduction in California.

Classification.—The commonly cultivated alfalfas of this country may be classified into five more or less distinct groups. Each group contains strains or varieties which differ to some degree. The groups are: (1) common; (2) Turkestan; (3) variegated; (4) non-hardy; and (5) yellow-flowered.

The *common* group includes the ordinary purple-flowered, smooth alfalfa, of which there are many regional strains grown throughout the western part of the United States. The term "common alfalfa" includes all of the alfalfas that are not clearly of hybrid origin or that do not have fairly distinct and uniform varietal characteristics.

The common group contains two general types of plants. One, as compared with the other, grows off more quickly after being cut, produces heavier yields, is more erect, has smaller crowns, which are produced above the surface of the ground, and is less resistant to winter conditions. The other type is slightly procumbent, has broad crowns which are produced somewhat below the surface of the ground, and is hardy. These facts are the basis for the production of regional strains. Some of the regional strains of common alfalfa are "Kansas grown," "Montana grown" and "Dakota grown."

The *Turkestan* group includes the alfalfa produced from seed coming from that country, regardless of its characteristics or history. The plants have purple flowers and it is practically impossible, when only a few plants are considered, to distinguish Turkestan from common alfalfa. However, the Turkestan plants are somewhat shorter and more spreading in habit of growth and slightly more hairy than common alfalfa. It was first supposed that this alfalfa would be suited to the cold, dry regions of this country. However, tests have shown that commercial Turkestan alfalfa yields less than the American-grown strains, is shorter lived and

is less hardy than such varieties as Grimm and Baltic. Turkestan alfalfa can, in most cases, be identified by the seed of Russian knapweed (*Centaurea picris*), which it nearly always contains. The name Turkestan is applied to all the seed sold in this group.

The *variegated* group is thought to have originated from hybrids between the ordinary purple-flowered alfalfa and the yellow-flowered species. Subsequently, intercrossing occurs and there is a considerable range of flower colors with purple predominating. However, brown, green, greenish-yellow and smoky hues occur, but occasionally pure yellow flowers appear. In addition to the flower colors, variegated alfalfa can be often identified by the form of the seed pods. Some of the pods are circular, semicircular or loosely coiled, but the predominating number resemble closely the compactly coiled pods of the common alfalfa. As a rule, the variegated alfalfas are more resistant to cold and drought than the other commercially grown alfalfas. The main varieties of this group are Grimm, Baltic, Canadian variegated and Sand Lucern.

The *non-hardy* group is distinct from the regional strains of common alfalfa but has been developed in the southern part of the United States. The varieties of this group recover quickly after cutting and have a long period of growth, but are seriously affected by low temperature. The two strains of this group grown commercially in this country are Peruvian and Arabian.

The *yellow-flowered* group includes various forms of yellow-flowered species. They are frequently called Siberian or sickle alfalfa. However, not all yellow-flowered alfalfas came from Siberia. The yellow-flowered alfalfas can be readily distinguished from those of other groups by the yellow flowers and crescent or sickle-shaped pods. The plants are usually procumbent, and the tap root is usually lacking. The root system, however, is much branched and the crowns are produced somewhat below the surface of the ground. This group is cold and drought resistant.

These alfalfas are of but little commercial value in the United States but on account of their hardy characteristics they may prove of worth for hybridizing purposes. Two varieties of this group are Semipalatinsk and Orenberg.

Distribution of Varieties and Strains.—The section of the country in which certain varieties and strains of alfalfa predominate is shown in Fig. 141. The different kinds of alfalfa frequently have different adaptations, and for this reason a variety which does well in one region may not be adapted to another region. The Peruvian alfalfa is adapted to the extreme southern and western parts of the United States, but it does not thrive in the other sections as well as some other sorts. In the selection of strains or varieties of alfalfa, the results of tests carried on in the region in question should be studied and adapted to the kinds chosen.

Value of Varieties.—A number of varieties of alfalfa have been described by Oakley and Westover (1916) and descriptions are to be found in other publications of the United States Department of Agriculture. The results of variety tests show that there are wide differences in adaptation of varieties and strains of alfalfa.

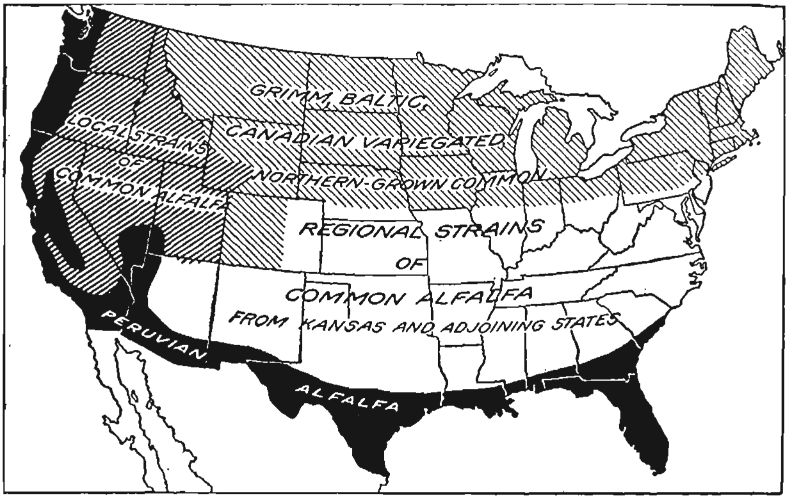

Fig. 141.—Outline map of the United States showing the varieties or strains of alfalfa that are recommended for various sections based upon climatic conditions. (*U. S. Dept. Agr. Farmers' Bul.* 757).

The cold resistance of different alfalfas at Dickinson, North Dakota, during the winter of 1908–1909 is given in Table CXV as reported by Brand and Waldron (1910). There were 68 varieties and strains in the test and they were planted in the spring of 1908 both in drilled rows and in hills. The minimum temperature was −31° F. and there was no snow covering during the coldest weather. The drilled rows were less severely affected than the hills.

Table CXV.—Average Mortality of Varieties and Strains of Alfalfa Planted in Hills and Drilled Rows at Dickinson, North Dakota, 1908–1909

Source	Mortality Per Cent
5 strains from South America	99.6
2 strains from Africa	100.0
2 strains from Russia	83.9
5 strains from Germany	83.1
5 strains from France	89.6
1 strain from Italy	98.7
1 strain from Spain	100.0
4 strains from Arabia	100.0
12 stra ns from Turkestan	72.3
3 strains from Mongolia	33.5

TABLE CXV.—AVERAGE MORTALITY OF VARIETIES AND STRAINS OF ALFALFA PLANTED IN HILLS AND DRILLED ROWS AT DICKINSON, NORTH DAKOTA, 1908–1909 (*Continued*)

Source	Mortality per cent
2 strains from Canada	45.4
2 strains from Mexico	85.0
18 strains from United States	83.3
10 strains from Utah	90.4
1 strain from Colorado	86.1
1 strain from Kansas	84.8
3 strains from Nebraska	76.4
3 strains from Montana	65.4
1 strain Grimm alfalfa from Fargo, N. D	2.8
1 strain Grimm alfalfa from Clearwater, Minn	7.0
1 strain Turkestan alfalfa from Highmore, S. D	9.2

The difference in yielding ability of different varieties and strains of alfalfa under different conditions is shown in Table CXVI.

TABLE CXVI.—YIELDS OF HAY IN POUNDS PER ACRE OF SEVERAL VARIETIES AND STRAINS OF ALFALFA GROWN IN VARIOUS REGIONS OF THE UNITED STATES

Source or kind of seed	Brookings, S. D., 4-yr. aver. (1)	Highmore, S. D., 5-yr. aver. (2)	Wyoming, 5-yr. aver. (3)	Texas, 1914 (4)	Yuma, Ariz.,† 1915 (5)
Turkestan	3,223	846	7,800	5,920	2,675
Kansas	.....	1,176			
Utah	2,988	.....	6,200		
French	2,573	.....	......	.....	3,583
Montana	2,960	.....	9,120		
Texas	3,045				
Northern Montana	3,003				
Peruvian (hairy type)	.....	.....	......	.....	3,859
Nebraska	3,160				
New York	3,008				
Grimm	.....	747	10,500	3,860	
German	.....	981*	7,800		
Sand Lucern	.....	.....	7,340	3,600	
Provence	.....	.....	6,620	3,440	
Native seed	.....	.....	8,760		

(1) Hume and Garver (1912).
(2) Hume and Champlin (1916).
(3) Parsons (1916).
(4) Dickson (1917).
(5) Freeman and Uphof (1915).

* Two cuttings only.
† Average 2 strains.

Botanical.—Alfalfa belongs to the family *Leguminosae* and genus *Medicago*. There are several species and frequently a number of varieties within a species.

The alfalfa plant is a perennial and the stems, which bear short, leafy branches, arise from the crown and usually vary in number from five to twenty. However, in rare instances a hundred or more stems may be produced. The plants vary in height from 18 inches to 3 feet. The seeds are borne in spirally twisted pods, which have one to three coils, each coil containing one to eight seeds.

The crown may be at the surface of the ground or slightly beneath and is made up of a series of short branches. Buds arise from any point on these branches; and generally as the first shoots reach maturity, new buds develop. In the humid regions the height of these new shoots is a good indication of the proper time for cutting the crop.

Roots.—The roots of alfalfa are very long and penetrate to a great depth as compared with most other field crops. Hays (1888), at the Minnesota Experiment Station, found the roots of 2-month old plants to be about 3 feet long. The tap root was present with small branches. At the age of 5 months the tap root had penetrated to a depth of 6½ feet, and some of the side roots were nearly as deep. It was noted that at a depth of 5 feet some of the larger roots possessed branch roots. Headden (1896) in Colorado observed roots 9 feet long on plants 9 months old. On plants 9 years old, growing on mellow, dry soil, but not irrigated, roots were found at a depth of 12½ feet. From two samples of plants, roots were secured measuring 11½ and 11¾ feet in length, respectively. Ten Eyck (1904), in Kansas, traced the roots of 3-year old alfalfa plants to a depth of 8½ feet. These data indicate that alfalfa plants very early develop extensive root systems and that the roots reach a comparatively great depth. The roots of the different kinds of alfalfa frequently differ. Common alfalfa produces a tap root with numerous branch roots of smaller size, and true rhizomes seldom occur, but the crown may become branched several inches beneath the surface of the ground. In the case of yellow-flowered alfalfa, the root system differs greatly from that of common alfalfa. In comparatively few cases is a single tap root developed, while in a majority of cases there is developed a rooting system. Abundant rhizomes are produced and sometimes aërial branches arise from the horizontal roots. The roots of variegated alfalfa have characteristics intermediate between the two previous groups.

Oliver (1913) has developed by hybridization, under greenhouse conditions, strains of alfalfa with numerous rhizomes. These forms also occur wild in Siberia.

Apparently the type of root system is important in the adaptation of alfalfa. According to Blinn (1911), from work done in Colorado, the more hardy types have spreading crowns with rhizomes and shoots with buds which the soil protects from freezing.

Pollination.—Piper and others (1914) have studied the pollination of alfalfa plants. These investigators found that about the same percentage

of seed set, when the flowers were self-pollinated as when pollinated with pollen from other flowers occurring on the same plant. However, crossing with pollen from other plants produced about 50 per cent more seed than self-pollination. It was also found that pollen from *Medicago falcata* plants were just as effective in fertilizing *Medicago sativa* flowers as pollen from other *sativa* plants. Insects bring about cross-pollination in alfalfa. Good seed crops are produced without their aid since flowers which are self-fertilized produce seeds freely.

In North Dakota Waldron (1919) planted together in equal numbers *Medicago sativa* and *Medicago falcata* plants; the seeds from each of the species were planted the following year and the number of hybrids determined. In the case of the *Medicago sativa* plants, 7.48 per cent were hybrids; and in the instance of the *Medicago falcata* plants, 42.7 per cent were hybrids. Perhaps some of the difference was due to the comparatively small number of flowers and more or less procumbent habit of growth in the case of *Medicago falcata*. These results indicate that alfalfa may be either self-pollinated or cross-pollinated.

Uses.—Alfalfa is used in many different ways and it is probable that no other forage crop produced in this country has so many different uses. The crop is high in feeding value and is excellent for general feeding purposes. About 80 per cent of the crop is made into hay. It is also used for pasturage, soiling, silage and making meal. Alfalfa is a good permanent cover crop and frequently increases the yield of succeeding crops, but it is not valuable as a green manure crop.

Culture

Seed.—In the selection of seed for seeding, it is important to consider the variety, the section of the country where it was produced and the quality of the seed in regard to purity and germination.

In respect to the purity of alfalfa seed, it is important to secure seed free from weed seeds, especially those which are noxious, such as dodder and Russian knapweed. The other impurities which are likely to occur should receive consideration and only seed tested for high purity should be planted.

The viability of the seed should be determined by germination tests, and only seed of high viability should be used. Plump seeds of bright olive-green color usually germinate well, while shriveled seeds or seeds of brownish color generally germinate poorly.

Climatic and Soil Requirements.—The bulk of the alfalfa crop is produced west of the Mississippi, mainly on account of the adaption of the crop. A dry, hot climate is most suitable but alfalfa will not thrive in hot, humid sections. Thus, it is found that the crop is mostly grown in the semi-arid sections, especially where irrigation is used.

Cold relations are also an important factor. It has been previously shown in this chapter that a temperature of −31° F. is very injurious to alfalfa. However, the varieties differ in cold resistance.

The soil requirement of the crop is probably next in importance to the climatic relation. Deep soils are necessary for alfalfa on account of the great root development; and good drainage is also essential. Under semi-arid conditions, alfalfa seems to thrive on nearly all soils with the exception of those containing much alkaline salts. In the East, where climatic conditions are unfavorable for the growth of alfalfa, the soil conditions must be especially favorable. In that part of the country, for successful results, a deep, fairly productive, well-drained soil, which contains an abundance of lime, is necessary.

Time of Seeding.—The time of seeding depends upon several factors, and it therefore varies in the different sections of the country. Late spring or early summer seeding is usually best in the Northwest, while in the Southwest the time of seeding ranges from the middle of August in the latitude of Washington, D. C., to October or November along the Gulf Coast. Spring seeding is generally followed in the semi-arid sections of the northern Great Plains. In the southern region of this area late summer and early fall seedings are recommended. In the irrigated sections of the Southwest, October is the best time of seeding, but good stands may be obtained by seeding any time between October 1 and April 15. When alfalfa is seeded in the fall, the seeding should be done so that the plants will secure sufficient growth to endure the winter; it should also be done late enough to escape the summer weeds. In the North, winter-killing is the great danger to be reckoned with in seeding, while in the South weeds are a great menace.

Methods of Seeding.—The methods vary in the different sections of the United States. In regard to the depth of seeding, this varies with the soil. With the proper moisture supply the seeds will germinate satisfactorily at depths up to 2 inches. As a rule, on the heavier kinds of soils, the seeds are covered from ½ to 1 inch. On sandy soils or in the semi-arid regions the seeding is deeper, about 1½ inches, to insure better moisture supply.

The seed may be sown by hand; from the seed attachment of the grain drill; it may be mixed with the fertilizer and sown from the fertilizer compartment of the drill; or various kinds of seed-distributing machines may be used. The object in any case should be to get the work done as cheaply as possible and to secure a uniform distribution of the seed. Williams (1917) in Ohio seeded alfalfa at the rates of 5, 10, 15, 20 and 25 pounds per acre, using both the broadcasting method from the seed attachment of a grain drill, and the drilling method with a clover drill. The average yield per acre for 2 years for the five different rates of seeding was 8,174 pounds for broadcast seeding and 8,381 pounds for drilling.

Nurse Crops.—The use of nurse crops is generally inadvisable. However, in spring seedings, when weeds are likely to be a factor, nurse crops may prove beneficial. In the East, South and in the semi-arid sections of the West, nurse crops should not be used. In the irrigated sections nurse crops may be planted, but even here the alfalfa usually succeeds in spite of the nurse crop. Spring barley and spring oats, the former more frequently, are generally used for the associated crop where any such crop is used.

Rates of Seeding.—The rate of seeding is greater in the East than in the West. In the latter region, under ideal conditions, good results have been obtained from the use of 1 to 5 pounds of seed per acre. Good yields are frequently secured from the use of 5 pounds. However, the rates of seeding are generally greater than these amounts. Oakley and Westover (1922) recommend 20 to 25 pounds per acre in the East; under irrigated conditions they recommend 15 to 20 pounds; and under dry land conditions, 8 to 12 pounds.

At the Ohio Experiment Station, Williams (1917) secured the following yields from different rates of seeding; 5 pounds of seed, 9,013 pounds of hay to the acre; 10 pounds, 9,148 pounds; 15 pounds, 8,735 pounds; 20 pounds, 8,613 pounds; and 25 pounds, 7,722 pounds. The yields are the average of 3 years from broadcast seeding from the seed attachment of the grain drill. Five pounds of seed gave results quite as satisfactory as the greater amounts but the weeds were more of a problem. The use of 10 pounds of seed per acre is recommended.

Inoculation.—Unless the crop will become naturally nodulated, inoculation should be done artificially at the time of seeding. It is not probable that alfalfa production will be successful unless nodulation is present. Brooks (1914) in Massachusetts reports, for the year 1910 for one field, an increase in yield of hay of 0.95 of a ton per acre from inoculation as compared with no inoculation, and an increase of 0.37 of a ton from another field. Fairfield (1910, page 442) at Lethridge, Alberta, reports an increase in yield of 1,822 pounds per acre for inoculation on non-irrigated land in 1908; on irrigated land (Fairfield, 1910, page 456) the increase was 4,050 pounds.

Harvesting.—The proper time for the harvesting of the alfalfa crop has been discussed in a previous chapter. In the West the crop is usually cut in early bloom, while in the East the development of basal shoots is a better criterion. In the East the plants often fail to bloom profusely. Where the shoots are the determining factor as to time of harvesting, they are allowed to become from 1 to 2 inches high before the crop is cut.

Cultivation.—In most alfalfa-growing sections the stands have a tendency to become thinner as they become older, and as a result native grasses, especially bluegrass and Bermuda grass, as well as weeds, begin to come in. Cultivation of the alfalfa soon after cutting not only destroys

the grasses and weeds to a great extent but seems to invigorate the alfalfa. There are several inplements with which the cultivation is done, such as the spring-tooth harrow, alfalfa cultivators, spike-tooth harrow and the disk harrow. The latter implement should not be used unless the ground is extremely hard. It does not give the good results so often attributed to it, as shown by work done at the Kansas Experiment Station. Ten Eyck (1908) in Kansas reports the 3-year average yield of disked alfalfa as 9,922 pounds per acre and of alfalfa not disked 10,269 pound.

Pasturing Alfalfa.—Alfalfa is an excellent hog pasture but under certain conditions it causes cattle and sheep to bloat. When grass is sown with the alfalfa in about equal parts, this trouble is reduced to the minimum.

In the use of alfalfa as pasture the principle of light grazing should be borne in mind and the number of animals maintained in the field should be consistent with securing two light cuttings of hay per season. Alfalfa should not be grazed the first year after planting, and but lightly the second year. Close grazing for one season will badly injure the crop but proper grazing is not injurious.

In dry regions the danger to animals from bloating and the damage to the crop from close grazing are not nearly so great as in the humid regions.

Seed Crop.—The commercial seed crop of alfalfa is mainly grown in the semi-arid regions of the West. When seed production is desired under irrigated conditions, the water is withheld from the crop. Seed production is seldom profitable in the humid regions of the country.

Alfalfa requires a dry, hot season for the greatest production of seed and it is customary to appropriate for seed the crop which will mature in the driest and hottest part of the season. In the northern states this is the second crop, but south of Kansas the third crop is generally saved.

The yield of seed varies from season to season, but a yield of 2 to 5 bushels per acre is considered fair, and a yield of 8 bushels is a large crop. The principal seed-producing states are Utah, Kansas, Nebraska, California and Arizona.

The crop, when harvested for seed, should be cut when about three-fourths of the pods are brown and the seeds have become yellow and hardened.

CHAPTER XLIV

SOYBEANS (Soja max)

The soybean is adapted mainly to temperate regions with fairly humid, warm growing seasons. In regions of tropical or subtropical climate, the plants often give good growth but the pods rarely fill. The soybean is less sensitive to frost than corn or cowpeas and is less affected by drought or wet weather than these two crops.

The soil requirement of the soybean is about the same as that of corn, provided inoculation is practiced; but on very poor soils it does not do so well as cowpeas. It does well on all kinds of soils but thrives best, other things being equal, on sandy or clay loams.

World Production.—According to Piper and Morse (1922) Manchuria produces more soybeans than all of the countries of the world combined. In 1921, Manchuria produced 4,520,000 tons of soybeans and in inner Mongolia there were produced 431,000 tons. During the period of 1917 to 1919 the average annual yield of soybeans in Japan was 544,890 tons, with an average yield of 16.46 bushels per acre. The yield in the United States in 1920 amounted to 68,340 tons, with an average yield of 14.6 bushels per acre.

Production in the United States.—The total yield of soybean seed in the United States in 1917 was 2,283,000 bushels and in 1919 the yield was 2,045,000 bushels. The average yield per acre for 1917, 1919 and 1920 was 14.8, 13.2 and 14.6 bushels, respectively.

In 1920 North Carolina produced 1,502,000 bushels, or 65.9 of the entire crop grown for seed. Virginia ranked second with 209,000 bushels of seed, or 9.2 per cent of the crop.

Historical.—The origin of the soybean is not known, as its cultivation is lost in antiquity. It has been cultivated in China and Japan for many centuries and certainly before the Christian Era.

The soybean is a native of eastern Asia and the wild form, a slender twining vine, *Glycine ussuriensis*, occurs in China, Manchuria and Korea. In the literature of 1804, the soybean is first mentioned as being grown in the United States. The Perry expedition brought back two varieties from Japan in 1854. Several other introductions were made and in 1898 the United States Department of Agriculture made numerous additional introductions. The production of the crop has increased rapidly in recent years and there is a probability that the soybean will become one of the leading farm crops of the United States.

Classification.—Piper and Morse (1922) have classified soybeans as follows:

1. *Length of Life Period.*—Under this heading are given seven groups based on results secured at the Arlington Experiment Farm. The groupings are:

(*a*) Very early, maturing in 80 to 90 days.
(*b*) Early, maturing in 90 to 100 days.
(*c*) Medium early, maturing in 100 to 110 days.
(*d*) Medium, maturing in 110 to 120 days.
(*e*) Medium late, maturing in 120 to 130 days.
(*f*) Late, maturing in 130 to 150 days.
(*g*) Very late, maturing in more than 150 days.

2. *Color of Seeds.*—Most varieties are uni-colored, such as straw-yellow, olive-yellow, green, olive, brown and black or a dark violet. A few varieties have seeds of more than one color, usually bi-colored, but some are tri-colored. The bi-colored are usually green or yellow with a saddle of black.

3. *Color of Pubescence.*—The plants of all varieties of soybeans possess pubescence and the amount of hairiness varies but little. There are, however, only two colors of pubescence. They are:

(*a*) White or gray. One of these colors occurs nearly always on grayish or straw-colored pods.
(*b*) Tawny. This color occurs nearly always on tawny-colored or dark pods. However, the black pods usually have white or grayish pubescence.

4. *Color of Flowers.*—There are two colors of flowers; namely,
(*a*) Purple.
(*b*) White.

Varieties and Their Distribution.—As shown in Fig. 142 the later and larger varieties are grown in the southern states for forage and seed purposes; the very early varieties are grown for seed production and the medium and medium late varieties are grown for forage in the northern states; while the medium and medium late varieties are grown in the intermediate section for seed and the same varieties and later ones for forage.

There are approximately 800 varieties of soybeans. However, the seedsmen and growers in the United States handle only about 20 varieties. The considerations in the choice of varieties are yield, habit of growth, coarseness, color of seed, ability to hold leaves, propensity to shatter seed, length of growing season, disease resistance and oil content. Therefore, the determination of the best variety for a locality will depend on whether it is to be grown for seed, for forage or for general purposes.

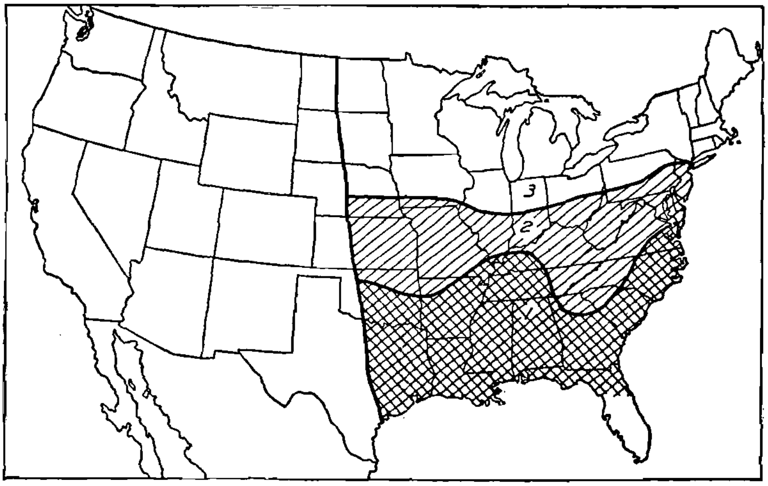

FIG. 142.—*Outline map of the United States showing the areas to which the soybean is especially adapted, as to varieties and purpose:* 1, *The later and larger varieties, for seed production;* 2, *medium and medium-late varieties for seed and the same varieties and later varieties for forage;* 3, *very early varieties for grain production and the medium and medium-late varieties for forage and ensilage.* (*U. S. Dept. Agr. Farmers' Bul.* 973).

TABLE CXVII.—SHOWING NUMBER OF SEEDS PER BUSHEL AND DAYS REQUIRED TO MATURE SEED FOR SEVERAL VARIETIES OF SOYBEANS

Variety	Number of seeds per bu.	Number of days to maturity
Barchet	645,000	160
Biloxi	112,000	165
Black Eyebrow	148,000	110
Chestnut	195,800	105
Chiquita	242,000	135
Early Brown	182,400	110
Ebony	194,400	120
Elton	130,000	110
Haberlandt	144,000	125
Hahto	74,800	130
Hollybrook	157,400	135
Ito San	198,900	105
Laredo	466,500	140
Mammoth Yellow	128,700	145
Mammoth Brown	111,300	135
Morse	149,700	130
Tarheel Black	163,200	140
Virginia	207,300	125
Wilson	144,000	120
Wilson-Five	301,400	120

Composition.—Piper and Morse (1922, Chapter VII) report that of the entire soybean plant 25.45 per cent is stems, 40.18 per cent leaves, and 34.37 per cent pods. The seed consists of cotyledons, 90 per cent; embryo, 2 per cent; and seed coat, 8 per cent. The composition of the different parts of the soybean plant at various stages of growth is shown in Table CXVIII taken from Piper and Morse (1922, page 103).

Table CXVIII.—Composition of the Different Parts of the Soybean Plant at Different Stages of Growth, at Arlington Farm, Virginia

	Moisture, per cent	Protein, per cent	Fat, per cent	N-free extract, per cent	Fiber, per cent	Ash, per cent
Roots:						
Full bloom	5.33	9.31	0.76	32.66	45.76	6.18
Pods ½ grown	5.21	8.76	0.93	32.88	46.85	5.38
Plants mature	4.91	3.59	0.56	27.00	59.09	4.85
Stems:						
Full bloom	4.72	10.44	0.56	35.43	43.31	5.54
Seed ½ grown	3.82	12.34	0.45	34.97	43.67	4.75
Plants mature	4.84	3.33	0.67	30.86	57.72	2.58
Leaves:						
Full bloom	5.72	19.56	2.08	49.85	14.65	8.14
Seed ½ grown	6.04	19.56	2.61	47.06	14.87	9.86
Pods:						
Seed ½ grown	5.57	18.53	1.50	41.03	25.31	8.06
Plants mature	6.53	5.26	1.40	45.01	35.61	6.19
Seed:						
Seed ½ mature	5.84	37.38	12.02	30.45	8.07	6.24
Plants mature	5.36	37.56	18.61	29.28	4.64	4.55

The composition of the different parts varies to a great degree as the plant approaches maturity.

Botanical.—The soybean (*Soja max*) is a member of the family *Leguminosae.* The plant is an annual, determinate in growth; most varieties are erect and branch from a definitely defined main stem. The branches may be spreading or ascending, and short or elongated, as in the case of the lower branches. In some varieties there is a tendency to twine, and the plants are suberect to procumbent. However, the form of the plants is greatly modified by environmental influences.

There is a great variation in shape, size, color and persistence of the leaves of the different varieties. In practically all varieties the leaves turn yellow as the pods ripen and fall off when the pods are mature.

However, some varieties, such as the Wisconsin Black, possess green leaves even when nearly all the pods are mature.

Inflorescence.—The flowers are borne on short axillary or terminal racemes and there are usually eight to sixteen flowers in a cluster. The flowers, which are white or purple, are nearly always without odor.

The flowers are normally self-pollinated and completely self-fertile. The different varieties cross readily and it is estimated that the amount of natural cross-pollination is but 1 to 2 per cent. The amount of natural crossing would probably be greater were it not for the fact that the pollen is shed about the same time the flowers open.

Uses.—The soybean has a great diversity of uses. In the Orient the crop is grown mainly for seed, which is used for human consumption and for the manufacture of food products. In this country the crop is grown largely for forage and green manuring purposes, but the production of seed for the soybean oil industry is rapidly growing.

The various ways in which the crop may be utilized is shown in Table CXIX as taken from Piper and Morse (1922, page 129).

TABLE CXIX.—SHOWING THE VARIOUS WAYS IN WHICH THE PLANTS AND SEEDS OF SOYBEANS ARE UTILIZED

Soybeans	Plants	Green manure				
		Forage	Hay			
			Ensilage			
			Soiling			
		Pasture				
	Seeds	Meal	Human food	Breakfast foods		
				Diabetic foods		
				Flour	Bread	
					Cakes	
					Muffins	
					Biscuit	
				Infant foods		
				Macaroni		
				Crackers		
				Milk		
			Stock feed			
			Fertilizers			
		Oil	Glycerin			
			Explosives			
			Enamels			
			Varnish			
			Food products	Butter substitute		
				Lard substitute		
				Edible oils		
				Salad oils		
			Waterproof goods			
			Linoleum			
			Paints			
			Soap stock	Soft soaps		
				Hard soaps		
			Celluloid			
			Rubber substitute			
			Printing inks			
			Lighting			
			Lubricating			
		Food products	Dried beans	Soy sauce		
				Boiled beans		
				Baked beans		
				Soups		
				Coffee substitute		
				Roasted beans		
				Vegetable milk	Cheese	Fresh
						Dried
						Smoked
						Fermented
					Condensed milk	
					Fresh milk	
					Confections	
					Casein	
				Breakfast foods		
			Green beans	Green vegetables		
				Canned		
				Salads		

Oil.—In the manufacture of oil from soybeans, by the expeller process, 1 ton of beans will yield on the average 32 gallons of oil (about 7.5 pounds to the gallon) and 1,600 pounds of cake. The difference of 130 pounds represents loss due to cleaning and loss of moisture. However, the percentage of oil will vary. The soybean meal made by grinding the cake contains 44.65 per cent protein, 8.77 per cent fat, 27.12 per cent nitrogen-free extract, 5.89 per cent ash and 5.96 per cent fiber.

Hay.—The value of soybeans for hay is indicated by their analyses. The percentage of protein, on the average, is 11.7 per cent; carbohydrates, 39.2 per cent; and fat, 1.2 per cent. The straw analyses show 2.8 per cent protein; 38.5 per cent carbohydrates; and 1 per cent fat.

Silage.—Piper and Morse (1922, page 139) give the average analysis of soybean silage as 72.68 per cent water; 3.93 per cent protein; 9.02 per cent carbohydrates; 2.44 per cent fat; 3.51 per cent ash; and 8.32 per cent fiber.

Soybeans, in addition to being suitable for hay and silage purposes, have a useful place as a pasturage or soiling crop.

Culture

Seeds.—Care should be used in choice of the variety, since great differences frequently exist. Varieties should be chosen which are suitable for the purpose for which they are desired and they should be adapted to the conditions under which they are to be grown.

Since soybean seeds lose their vitality rapidly, one should not sow seed 2 years old without first determining their germination. Farmers should use care in curing and storing soybean seeds since these seeds are easily injured and their viability will be readily destroyed if they are not properly handled.

Time of Seeding.—The soybean crop should not be seeded until danger of frost is over. The plants grow very slowly when the ground is cold, and extremely early seedings are, therefore, inadvisable. However when seeded too late, the crop may not mature before frost in the fall. As a rule seeding takes place about the same time corn is planted, or slightly afterwards.

Mooers (1908) at the Tennessee Experiment Station, conducted a series of dates of seeding tests from April 3 to August 6. The June seedings proved the most successful.

The results secured at the Arlington Experimental Farm, where the Haberlandt variety was used as reported by Piper and Morse (1922, page 60) are shown in Table CXX.

Rate of Seeding.—The rate of sowing depends on the size of seed, the purpose for which the crop is grown and the method of seeding. When the crop is seeded in rows from 2 to 3 feet apart, the usual rate of

TABLE CXX.—ACRE YIELDS OF SEED AND HAY OF SOYBEANS AT DIFFERENT DATES OF PLANTING AT ARLINGTON FARM, VIRGINIA

Date of planting	Green forage, tons		Hay, tons		Grain, bu.	
	1915	1916	1915	1916	1915	1916
May 1	8.92	8.70	2.09	1.96	33.3	27.6
May 15	10.06	8.36	2.39	2.09	34.0	25.3
June 1	8.55	4.22[1]	1.90	1.03[1]	33.3	10.3[1]
June 15	7.54	7.84	1.83	2.00	25.3	21.3
July 1	7.18	7.97	2.00	1.82	24.3	23.6
July 15	6.18	4.27	1.50	1.12	19.3	12.0
August 1	2.63	3.64	0.87	0.94		

[1] Poor stand due to destruction of the seedlings by pigeons.

seeding is approximately 20 to 30 pounds per acre. In the case of broadcast sowing, the usual rate is 1 to 1½ bushels of seed to the acre. The results of rate of seeding tests as reported by Piper and Morse (1922, page 64) are shown in Table CXXI.

TABLE CXXI.—ACRE YIELDS OF SOYBEAN HAY AND SEED WHEN PLANTED AT DIFFERENT RATES

Rate of seeding to the acre, lb.	Width of rows, in.			Threshed grain, bu.			Hay, tons		
				Ohio	Indiana	Tennessee	Ohio	Indiana	Tennessee[1]
15	28	.....	..	20.26	....	....	1.62	....	
30	28	24, 28	36	20.31	20.8	15.4	1.62	2.85	2.39
36	..	.....	30	.....	....	18.5	....	....	3.13
40	..	8	..	.....	21.1	....	....	3.05	
45	28	.....	24	22.49	....	16.3	1.77	....	2.77
60	28	.....	18	22.05	21.7	24.5	1.70	3.18	2.74
90	..	.....	..	.....	20.9	....	....	2.95	
120	8	.....	8	19.68	....	12.2	2.07	....	2.94

[1] Straw.

Depth of Seeding.—The depth of seeding is of special importance in the case of soybeans, since poor stands are often the result of seeding too deeply, especially on soils which have a tendency to form a crust on the surface. As a rule, on the heavier types of soil, the depth of seeding should not exceed 2 inches, while in sandy soils the planting may be as deep as 2 to 4 inches.

Inoculation.—The soybean, in common with other legumes, utilizes the nitrogen of the atmosphere through the bacteria which live in the

nodules on the roots. Soybeans are inoculated only with the bacteria from soybean nodules. Therefore, care should be used to make sure that the plants become inoculated by artificial means, if natural inoculation is not to be had. Experimental results show that inoculated plants as a rule contain more protein and produce more dry matter than uninoculated plants.

Methods of Seeding.—The grain drill is probably the best machine with which to seed soybeans, either in rows or broadcast. If some of the openings in the feed box of the drill are stopped, the width of rows can be regulated.

FIG. 143.—A field of Mammoth Brown soybeans.

As a rule, seeding in rows is preferable to broadcasting with the drill. Seeding in rows will make necessary several cultivations of the crop but this cost will usually be balanced by the difference in cost of seed. The cultivation will also destroy the weeds. When the crop is to be used for hay, for soiling, or for green manure purposes, and when a fine quality of forage is desired broadcasting the seeds with a grain drill may be advisable where the land is comparatively free from weeds.

The spacing of rows depends upon the variety and productiveness of the land. As a rule, the spacing is from 2 to 3 feet; but when the crop is to be used for seed and harvested with a soybean harvester, the rows should be farther apart, usually 39 to 40 inches.

Time of Cutting for Hay.—It is best to cut hay when the pods are well formed. If the crop is cut earlier, the yield is less, and the crop is more difficult to cure but the percentage of protein is higher than when cut later. When the crop is allowed to stand too long, there is a loss of leaves, the stems become more fibrous and the feeding value is less.

Curing Soybean Hay.—Since soybeans have rather coarse stems which dry slowly as compared with the leaves, a somewhat different method of curing must be used than commonly followed for ordinary

hays. However, soybean hay is more easily cured and handled than cowpea hay. The plants should be allowed to remain in the swath until the leaves have thoroughly wilted but not until they become dry and brittle. The hay should then be raked into windrows and left there 2 or 3 days, according to the kind of weather; it should then be placed in small cocks or shocks. Under favorable curing conditions it usually requires 5 or 6 days to cure soybean hay in good condition.

The curing process can be facilitated by the use of curing frames or poles with cross-pieces near the bottom. The frames are usually three- or four-sided pyramids consisting of boards or poles 3 to 6 feet long, fastened together at the top and held by cross-pieces near the bottom. The hay is thus held off the ground. In this way the circulation of air is aided and curing is more rapid.

Time of Cutting for Seed.—Since most varieties of soybeans shatter their seeds rather badly when mature, attention should be given to avoid this loss. As a rule, the leaves of the soybean plants turn yellow and drop off by the time the pods are mature. In case the bean harvester is not used, it is best to cut when nearly all of the leaves have fallen and practically all the pods have turned in color. When the harvesters are used, the crop should be allowed to reach maturity.

Methods of Harvesting Seed.—There are several ways by which the seed may be harvested. The ordinary mowing machine with a side-delivery attachment, the self-rake reaper and the grain binder are sometimes used to harvest the crop. When cut, the plants are put into small piles or shocks for several days, and are then threshed with the ordinary threshing machine. In this process the speed of the cylinder is reduced about one-half, and some of the spikes in the concaves are removed; the speed of the fan and of the other parts of the separator, however, is maintained. However, unless the threshing is done by an experienced person, many cracked beans are likely to be obtained. The beans may also be removed from the vines by the use of a flail.

There are on the market at the present time several types of special bean harvesters, which usually give good results, since they save labor and time, although the loss of beans is not entirely eliminated.

CHAPTER XLV

MISCELLANEOUS CROPS

In the preceding chapters, the principal crops have been discussed and a lack of space prevents a full discussion of those of lesser importance. However, in the present chapter certain crops of secondary importance, when the country as a whole is considered, will be briefly treated.

COWPEAS

The cowpea (*Vigna sinensis*) is grown most extensively in the southern states, as shown in Fig. 144. It is a warm weather plant and is injured

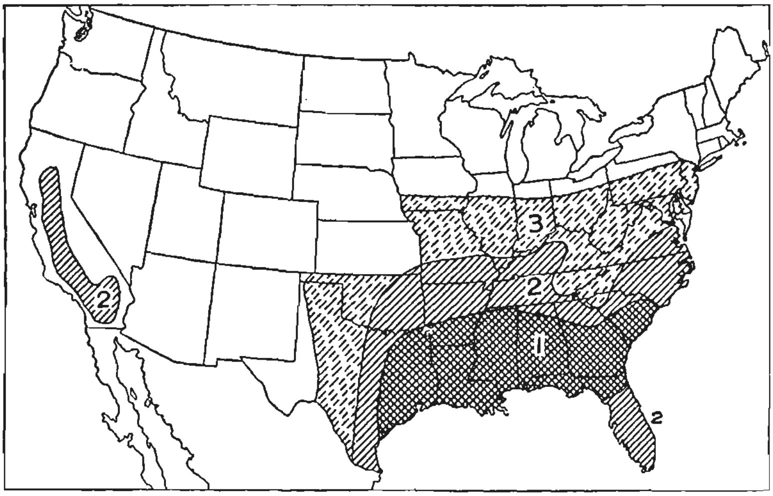

FIG. 144.—Outline map of the United States showing the comparative distribution of cowpeas. 1, Area in which cowpeas are grown most extensively; 2, area in which cowpeas are grown quite generally; 3, area in which cowpeas are grown to some extent. (*U. S. Dept. Agr. Farmers' Bul.* 1148).

by slight frost. Cowpeas will stand considerable drought and a moderate amount of shade. The crop succeeds on nearly all kinds of soils. It is apparently better adapted to more kinds of soils and will make better growth under adverse conditions than most of the other legumes.

The total yield of cowpea seed in the United States in 1917 was 12,787,000 bushels; in 1919 the yield was 6,026,000 bushels. The average yield per acre for 1917, 1919 and 1920 was 7, 6.3 and 9 bushels, respectively. The three states, South Carolina, Alabama and Georgia, produced 5,189,000 bushels, or 58.3 per cent of the entire crop in 1920.

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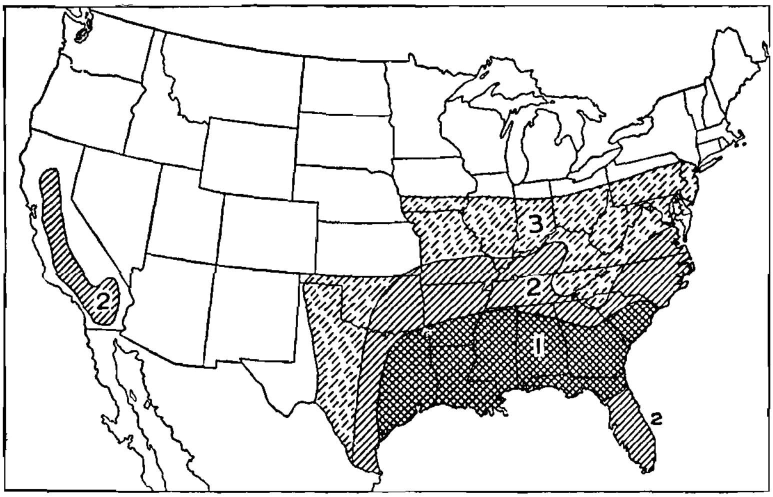

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Historical.—The cowpea is a native of central Africa. There the wild plant, which differs very little from the cultivated cowpea and with which it readily crosses, is widely diffused. The crop seems to have been cultivated since an early period. It was introduced into China in prehistoric times and was known in Europe at least as early as the Christian Era. It seems to have come to the United States at least as early as the latter part of the eighteenth century.

Classification.—The characteristics of the cowpeas vary greatly. As a rule, the plants are indeterminate in growth; that is, they continue to grow until killed by frost. These plants have long, trailing vines. The following classification will serve to show certain characteristics which may be used in distinguishing some varieties.

1. *Habit of Growth.*—Prostrate; procumbent; low, half-bushy; tall, half-bushy; and tree-like or erect.
2. *Color of Seeds.*—Dominant colors: black, white, and red.
   (*a*) Uniform in color or pattern.
   (*b*) Not uniform in color or pattern.
      (1) Spotted.
      (2) Marbled, as Whippoorwill.
      (3) Speckled, as Taylor and New Era.
      (4) Marbled and speckled, as Groit.
3. *Shape of Seeds and Pods.*—The shape of seed falls into five main divisions: reniform or kidney-shaped, subreniform, oblong, rhomboid and globose. The shape of the seed is closely related to that of the pod. The kidney-shaped seeds, which are the most common, develop in the pod separate from each other. The "crowder" or globose seeds are produced in long, slender pods, and are crowded closely together when developing; hence the name.

In shape, most of the pods are curved; in some varieties, however, the pods are straight and in a few cases they are coiled into one or two complete turns. With most varieties the pods are constricted between the seeds but in the case of some varieties, this characteristic does not occur as the pods are terete.

4. *Color of flowers.*
   (*a*) White or nearly white. This color is usually associated with white or partly white seeds.
   (*b*) Pale violet or purple.
5. *Time of ripening.*
   (*a*) Early, those maturing in from 70 to 80 days.
   (*b*) Medium, those maturing in from 90 to 100 days.
   (*c*) Late, those that require more than 100 days in which to mature.

Value of Varieties.—The cowpea is grown for two main purposes: for forage and for seed. The yields vary with the variety and conditions

of climate, soil and culture. The yields of different varieties at a number of the experiment stations, as reported by Morse (1920*a*) are given in Tables CXXII and CXXIII.

TABLE CXXII.—YIELDS OF HAY OBTAINED FROM IMPORTANT VARIETIES OF COW-PEAS AT DIFFERENT AGRICULTURAL EXPERIMENT STATIONS (AVERAGE YIELD PER ACRE IN TONS)

Variety	Ala., tons	Ariz., tons	Ark., tons	Ga., tons	Ind., tons	Kan., tons	Miss., tons	Mo., tons	N. C., tons	Okla., tons	S. C., tons	Tex., tons	Va.,[1] tons	Fla., tons
Black	1.12	....	2.03	0.81	1.76	2.23	2.27	1.74	1.32	1.56	0.81			
Brabham	....	....	....	1.12	....	....	1.80	....	1.29	2.20	1.12	1.75	1.89	1.26
Clay	1.42	0.56	2.88	0.60	1.93	1.94	2.27	2.11	0.97	1.36				
Early Buff	....	0.77	....	....	....	....	....	....	....	....	....	0.78	1.48	
Early Red	....	1.56	....	....	....	....	....	....	1.31	....	....	....	1.54	
Extra Early Blackeye	0.71	....	1.06	....	....	2.17	....	1.56	1.28	....	....	....	0.71	
Groit	1.23	....	....	....	....	....	2.04	2.08	1.47	1.49	....	1.38	1.90	0.48
Iron	1.55	....	....	1.03	1.97	....	1.98	1.47	1.35	1.66	1.08	0.93	1.88	1.01
Large Blackeye	....	....	....	0.98	....	....	1.63	....	1.25	....	0.98			
Michigan Favorite	....	....	....	....	1.68	2.10	....	1.63						
Monetta	....	2.44	....	....	....	....	....	....	1.53	....	....	1.60	1.84	
New Era	1.15	....	0.65	0.45	1.57	2.14	1.77	1.76	1.14	1.11	1.15	....	1.69	0.53
Red Ripper	1.86	....	1.73	0.93	....	....	2.21	1.88	1.07	1.70	1.86	1.38	....	0.66
Taylor	....	0.64	1.86	0.70	....	2.47	2.17	....	1.26	1.74	....	1.10	1.81	
Unknown	1.57	....	2.46	0.66	....	....	2.33	....	1.88	2.14	1.55	....	....	1.03
Whippoorwill	1.36	....	0.91	0.86	1.55	2.63	1.92	1.81	1.41	2.15	0.86	0.69	1.83	0.92

[1] Arlington Experiment Farm.

TABLE CXXIII.—YIELDS OF SEED TO THE ACRE OF THE BEST VARIETIES OF COW-PEAS AT DIFFERENT AGRICULTURAL EXPERIMENT STATIONS (AVERAGE PER ACRE IN BUSHELS)

Variety	Ala., bu.	La., bu.	Ariz., bu.	Ark., bu.	Del., bu.	Ga., bu.	Ind., bu.	Kan., bu.	Miss., bu.	Mo., bu.	N. C., bu.	Okla., bu.	S. C., bu.	Tex., bu.	Va.,[1] bu.
Black	21.1	*13.0*	....	15.7	7.4	19.9	8.1	11.1	14.2	18.6	12.9	....	13.0	*20.3*	*20.0*
Brabham	....	....	....	....	....	11.1	....	....	29.1	....	10.0	....	....	4.0	10.6
Clay	10.8	....	....	9.8	6.6	34.3	5.3	10.9	14.0	14.4	13.7	....	13.3	2.1	
Cal. Blackeye	....	....	....	....	....	5.9	....	4.1	....	....	....	8.1	16.3	....	16.3
Early Buff	....	....	2.4	....	....	....	....	....	....	....	....	....	....	12.6	19.7
Extra Early Blackeye	16.4	....	....	29.1	5.4	....	14.2	9.9	....	....	9.2	....	9.9	7.2	18.8
Groit	....	....	....	....	8.2	....	....	....	26.8	14.8	17.3	2.2	....	8.3	27.3
Iron	14.9	5.0	....	....	7.4	15.8	7.2	2.5	14.8	17.5	8.3	3.3	9.3	14.3	10.9
Large Blackeye	17.0	6.0	....	23.6	5.6	31.3	....	12.7	17.1	14.8	21.7	....	21.7	17.0	26.3
Michigan Favorite	....	....	....	....	8.2	....	19.3	11.2	....	11.4	7.9	....	....	....	19.8
Monetta	....	....	6.4	....	....	....	....	....	....	....	10.9	....	....	1.3	13.2
New Era	22.0	18.7	....	39.9	15.6	6.9	14.0	12.4	22.3	14.0	14.7	5.0	24.2	9.6	25.2
Red Ripper	19.3	4.5	....	11.9	....	27.7	....	7.9	14.2	8.3	14.2	2.0	....	2.7	
Taylor	23.6	....	....	19.9	4.9	11.3	....	11.9	21.7	....	10.6	2.4	11.5	9.7	18.6
Unknown	14.7	....	....	2.5	3.5	30.5	....	0.5	10.0	....	4.4	1.5	....	13.4	
Whippoorwill	12.4	12.7	....	25.6	13.2	25.3	18.3	11.5	28.5	14.0	14.8	1.0	13.8	16.5	10.1

[1] Arlington Experiment Farm.

There are about 15 varieties of cowpeas in common cultivation, with a large number grown in a small way. The most valuable American

varieties of cowpeas for forage are the Whippoorwill, Iron and New Era, and their hybrids, the Brabham and Groit.

Uses.—The cowpea is used to a rather large extent in the southern states for human consumption. Cowpeas are commonly used in three forms: in the pod, shelled green and shelled dried. According to Langworthy and Hunt (1913) the green shelled cowpeas contain 9.4 per cent protein; 0.5 per cent fat; 23 per cent carbohydrates; 1.4 per cent ash; moreover, they have a food value of 620 calories per pound. The dried cowpeas have 21.4 per cent protein; 1.4 per cent fat; 60.8 per cent carbohydrates; 3.4 per cent ash; and a food value of 1,590 calories per pound.

As has been discussed by Morse (1920*a*), cowpeas make an excellent hay when properly handled. The hay analyzes, on the average, 16.1 per cent protein; 40.3 per cent carbohydrates; 3.2 per cent fat; 10.2 per cent ash; and 19.8 per cent fiber. The crop is used to some extent as pasturage, especially for hogs. It is also used for silage purposes, especially for mixing with corn or sorghum; and it serves a very useful purpose as a green manure. The tops contain 1.96 per cent nitrogen, 0.51 per cent phosphoric acid and 1.93 per cent potash. The roots contain 1.18 per cent nitrogen, 0.55 per cent phosphoric acid and 0.93 per cent potash.

Culture

Time of Seeding.—Since the cowpea is injured by frost, it should not be seeded until danger of frost is over. After this danger is passed, the time of seeding depends largely on the purpose for which the crop is to be used. If seeded for hay or seed, the crop should be seeded early; but for green manuring and pasture purposes, the crop may be seeded late with good results ensuing. The results for dates of seeding tests are reported by Morse (1920) as shown in Table CXXIV.

Table CXXIV.—Yields per Acre of the Groit and New Era Varieties of Cowpeas in Time-of-sowing Tests

Date sown	Groit variety				New Era variety		
	Arlington Farm, Va.		Rocky Mount, N. C.		Date sown	Manhattan, Kan.	
	Hay, tons	Seed, bu.	Hay, tons	Seed, bu.		Hay, tons	Seed, bu.
May 1	1.39	28	0.74	12.8	May 12	1.19	7.16
May 15	1.55	28	0.94	16.0	May 19	2.00	10.32
June 1	1.58	29	1.09	17.1	May 26	2.00	9.91
June 15	1.80	19	1.17	14.3	June 3	2.26	10.68
July 1	1.74	12	1.25	15.4	June 9	2.08	11.59
July 15	1.10	5	0.84	13.3	June 16	1.77	5.96
Aug. 1	0.41	2	....	....	June 28	1.10	4.47

Rate of Seeding.—The rate of seeding will vary with the method of sowing. According to Morse (1920), when the seeds are seeded in rows 24 to 40 inches apart, the rate of seeding is usually about 30 to 40 pounds per acre. In broadcast seeding the seeds are sown at the rate of about 90 pounds to the acre.

Method of Seeding.—The cowpea crop is ordinarily sown in one of three ways: broadcast, in rows, and in mixture with other plants such as sorghum, Sudan grass, corn and so forth. The method used will depend largely on the purpose for which the crop is seeded. In case the crop is desired for forage or green manuring, the broadcast method is generally used, but for seed production the crop is generally seeded in rows. The rows are usually 2½ to 3 feet apart and the plants should stand 2 to 3 inches apart in the row. For hogging-off or for silage purposes, cowpeas are frequently seeded with corn, either at the time the corn is planted or at the last cultivation of the corn crop. They are also used for seeding with sorghum, Johnson grass, Sudan grass, millet and soybeans.

Morse (1920) reports as shown in Table CXXV the 3-year average yield of hay and seed for four varieties of cowpeas seeded broadcast at the rate of 90 pounds to the acre, and seeded in 18 to 40-inch rows at the rate of 45 and 30 pounds of seed to the acre, respectively.

TABLE CXXV.—AVERAGE YIELDS TO THE ACRE IN METHOD OF CULTURE TESTS WITH COWPEAS AT ARLINGTON FARM, VIRGINIA

Variety and method of culture	Hay, tons	Seed, bu.	Variety and method of culture	Hay, tons	Seed, bu.
Early Buff:			Brabham:		
Broadcast	1.32	10.7	Broadcast	1.83	3.9
18-inch rows	1.32	13.3	18-inch rows	1.90	14.6
40-inch rows	1.18	15.9	40-inch rows	1.66	16.0
Whippoorwill:			New Era:		
Broadcast	1.98	4.5	Broadcast		
18-inch rows	1.90	6.6	18-inch rows	1.52	16.4
40-inch rows	1.84	9.9	40-inch rows	1.26	15.3

Cultivation.—If the crop is seeded in rows, two or more cultivations are necessary to secure satisfactory yields. The ordinary corn-cultivating implements may be used and cultivation should cease about the time the plants begin to bloom.

Harvesting.—If the crop is harvested, it is usually for one of two purposes, hay or seed. The crop ripens unevenly and it is sometimes difficult to determine the proper stage for harvesting. Usually blossoms and green and ripe pods occur on the vines at the same time. However, as a rule, the crop is cut for seed when one-half to two-thirds of the pods

are ripe. There are various methods of harvesting, such as by hand, by special harvesters and by self-rake reapers.

When cut for hay the crop should be cut when most of the pods are fully developed and when the first ones have ripened. If cut much before this time, the hay is difficult to cure; and if the crop is harvested much later, there will be some loss due to shattering of seed and leaves and to the long and woody stems. The ordinary mowing machine is commonly used for harvesting cowpeas for hay.

MILLETS

Origin and History.—The earliest cultivation of the millets is prehistoric. They were used by the lake-dwellers of Switzerland in the Stone Age and as early as 2700 B.C. by the Chinese in a religious ceremony. The millets, which are native to southern Asia, spread to Europe in ancient times. According to Vinall (1917) a distribution of millet was made by the United States Patent Office in 1849 and by 1889 the crop was important in the United States. In 1899 more than 74 per cent of the acreage of millet was in the North Central states, and Kansas was the leading state, having 349,906 acres. In 1909 the leading states were Kansas, Missouri, Texas, Nebraska, North Dakota, Tennessee and Oklahoma. It may be said that the acreage seeded to millet decreased from 1,743,887 acres in 1899 to 1,117,769 acres in 1909.

Kinds.—The groups of millets as given by Vinall (1917) are given in Table CXXVI.

Table CXXVI.—Groups of Millet

Common Names	Botanical Names
Foxtail millet	*Chaetochloa italica* (L.) Scribner.
Italian millet	*Setaria italica* Beauv.
Proso Broom-corn millet Hog millet Russian millet	*Panicum miliaceum* L.
Barnyard millet Japanese millet Sanwa millet Billion-dollar grass	*Echinochloa frumentacea* (Roxb.) Link. (*Panicum frumentaceum* Roxb.)
Pearl millet Penicillaria Cat-tail millet Egyptian millet	*Pennisetum glaucum* (L.) R. Br. (*Pennisetum typhoideum* Rich.)
Ragi Finger millet Coracan	*Eleusine coracana* (L.) Gaertn.
Shama millet Jungle rice	*Echinochloa colona* (L.) Link.
Texas millet Colorado grass	*Panicum texanum* Buckl.
Kutki millet	*Panicum psilopodium* Trin.
Koda millet	*Paspalum scorbiculatum* L.
Little millet	*Panicum miliare* Lamarck.

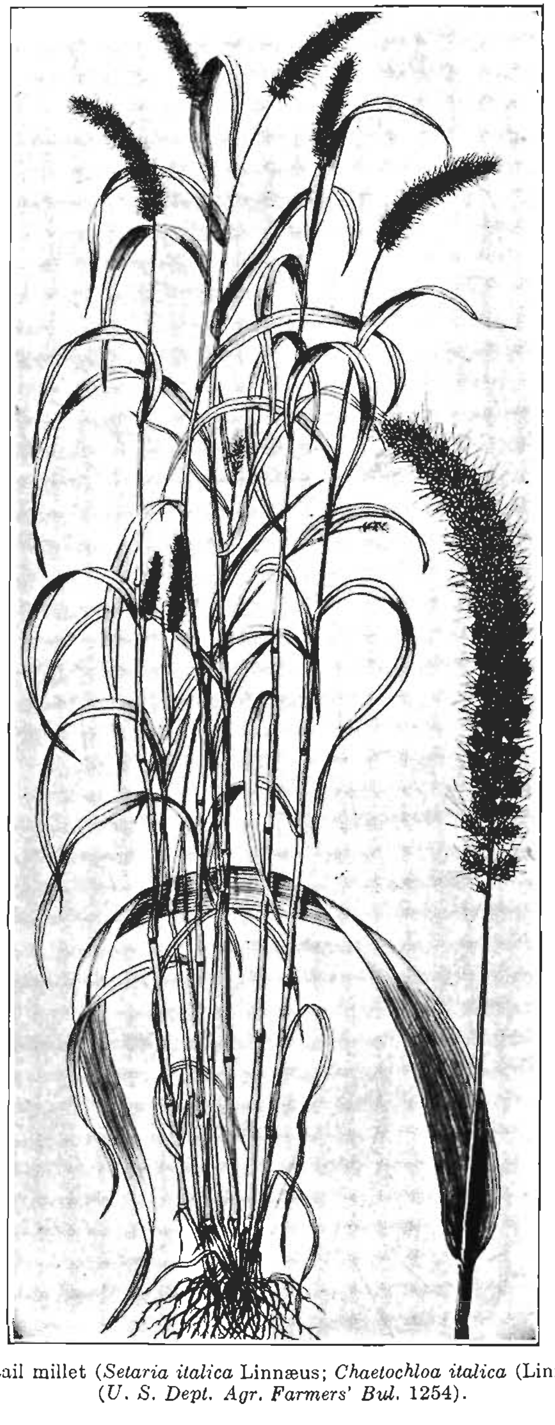

FIG. 145.—Foxtail millet (*Setaria italica* Linnæus; *Chaetochloa italica* (Linnæus) Scribner). (*U. S. Dept. Agr. Farmers' Bul.* 1254).

Foxtail Millet.—The foxtail group is the principal one and it constitutes 90 per cent or more of the millet acreage in the United States. The chief varieties of the group are Common, Golden or German, Hungarian, Gold Mine, Kursk and Turkestan.

Yield of Varieties.—The yield of certain varieties of foxtail millet in comparison with Proso and Sudan grass is given in Table CXXVII taken from Vinall (1917).

TABLE CXXVII.—YIELDS OF FOXTAIL MILLETS COMPARED WITH THOSE OF PROSO AND SUDAN GRASS

Locality	Length of test, yr.	Hay per acre, tons							
		Common	German	Kursk	Gold Mine	Hungarian	Turkestan	Proso	Sudan grass
Great Plains:									
Northern	5	1.66	1.56	1.79	1.36	1.62	1.73	1.38	2.19
Central	4	1.71	2.76	2.04	2.30	1.88	2.00	1.27	3.20
Southern	5	.....	2.12	1.27	1.62	1.37	2.44	.....	3.74
Northern Miss. Valley	7	1.80	2.15	2.16	.....	2.05	.....	2.04	3.38
Northeastern corn belt	7	2.55	3.72	.....	.....	2.80	.....	2.62	3.20
Southeastern states	4	.....	3.25	.....	.....	2.42	.....	.....	3.45

Adaptation of Foxtail Millet.—Foxtail millet, like other millets, requires warm weather during the growing season; where cool weather prevails during the summer, the crop does not thrive. However, in the northern Great Plains, where the summers are short but hot, millet is extensively grown. Fairly abundant rainfall is necessary as the crop does not revive after a drought as does sorghum; it may be said that millet has a low water requirement.

The crop does best on rich, well-drained soils high in organic matter. It has the reputation of being "hard on the land" but it is doubtful whether this report is true to any greater extent with foxtail millet than with other crops producing a similar yield in the same period of time. Even if there is any justification for this opinion regarding the effect of foxtail millet on land, farmers seldom fail to plant on this account.

Culture of Foxtail Millet.—The crop should not be seeded until danger of frost is over, and planting is usually not started until 2 or 3 weeks after corn is ordinarily planted. Since the crop is quick-growing and thrives best in hot weather, it is frequently used as a catch crop and may be planted any time during the summer. However, the last date of seeding should allow 60 to 70 days before frost. The crop is usually sown broadcast with the grain drill at rates varying from 2 to 4 pecks per acre.

Feeding.—Foxtail millet is used mainly for hay and it has about the same feeding value as timothy hay. The hay is slightly laxative to horses and when fed for a long time may cause increased action of the kidneys and slight swelling and inflammation of the joints. Apparently the hay does not have these effects on cattle and sheep.

VETCHES

Kinds.—There are a number of kinds or species of vetches; more than 120 have been recognized. However, there are two species mainly grown in the United States; hairy vetch (*Vicia villosa*), also called "winter vetch" and "sand vetch;" and common vetch (*Vicia sativa*), also called "Oregon vetch" and "spring vetch."

Common Vetch.—Common vetch is an annual. It is seeded in the fall in sections having mild winters and in the spring in regions where the winters are severe. The winter strains will usually withstand a temperature of 10° F. but zero temperature results in much damage. On the Pacific Coast and in the South, fall seeding is practiced; in the other sections spring seeding is preferable.

Adaptation.—Common vetch requires a cool growing season and hot summer weather is injurious. Well-drained soils are necessary and good soils are preferred, but fair growth is made on the poorer soils.

Culture and Uses.—The crop may be sown broadcast or drilled but the latter is probably the better method. When vetch is seeded alone, the rate of seeding is about 60 pounds (1 bushel) of seed per acre and the crop is usually seeded for green manuring purposes. When the crop is sown for hay, a mixture containing vetch and some small grain, frequently oats, is used. In such case, the rate of seeding varies from 30 to 60 pounds of vetch seed with equal weight of oats. Vetch also makes an excellent winter pasture.

Hairy Vetch.—Hairy vetch, a winter annual or biennial, differs agriculturally from common vetch in being more hardy and in acting as a biennial when seeded in the spring.

Adaptation.—The cold resistance of hairy vetch is shown by the fact that it seldom winter-kills in the northern part of the United States or in southern Canada. It is adapted to cool, temperate climates and does not do well under hot, summer temperature. The crop is drought resistant and especially suited to sandy or sandy loam soils, but it grows well on nearly all productive soils.

Culture and Uses.—The seeds may be sown broadcast or drilled but the latter method is usually preferable. When hairy vetch is seeded alone, the rate of seeding varies from 40 to 60 pounds per acre. However, the crop is usually sown with a small grain crop, such as rye. In a case of this kind, the small grain is seeded at the ordinary rate and the vetch

sown at the rate of 20 to 30 pounds per acre. The **crop is used for** hay, green manure, pasture and silage.

RAPE

Origin and History.—Rape (*Brassica napus*) is a native of temperate Europe and the wild form is an annual plant. The cultivated plants, however, are either annual or biennial. The annual sort is grown only for the seed, from which oil is obtained. The biennial kind is grown chiefly for forage.

Varieties.—The biennial form, of which there are several varieties, is the one largely grown in this country, the Dwarf Essex being the principal variety. Another variety is the Victoria or Dwarf Victoria rape, a variety which at best is not superior to Dwarf Essex. The biennial type lives through the winter under such mild climates as we find on the Pacific Coast and in the South; under more severe climates it is killed by late fall frosts.

Adaptation.—Rape is best adapted to cool, moist climates such as prevail in the northern part of the United States. However, by seeding so that the crop will be largely produced in the cooler portion of the growing season, farmers can grow this crop successfully in other sections of the country.

Rape does not give large yields on poor soils. For high yield, rich, moist soils are necessary. The crop is a gross feeder and can be well grown on recently drained swamp lands and newly cleared woodlands.

Culture

Methods and Rates of Seeding.—Rape may be sown in cultivated mws; it may be drilled; it may be sown broadcast; and it may be sown in roixtures with some other crop, such as oats. When seeded in cultivated rows, the crop is usually seeded at the rate of 2 or 3 pounds of seed per acre in rows 24 to 28 inches apart. In case the seeds are drilled, the rate of seeding is 4 to 6 pounds per acre with the same or a slightly higher rate for broadcast seeding. In seeding with small grain, one should generally use 3 to 5 pounds of seed per acre. The method of seeding in cultivated rows is usually followed when the crop is hogged-off.

Time of Seeding.—As a rule, the crop is ready to be grazed in from 10 to 12 weeks after seeding. The time of seeding will vary with the locality but in any section the crop is seeded to utilize the cooler portion of the growing season. The crop is, therefore, generally sown in the early spring or late summer. In general the seeding in the northern states varies from May 1 to the last of July. In the South the crop may be seeded in September or October.

Uses.—Rape is an excellent pasture crop for hogs and sheep and is also used for pasturing cattle. In case of sheep and cattle, however, there is danger of bloating. Rape is used to some extent as a soiling crop.

FIELD PEA

Origin and History.—The field pea (*Pisum arvense*) is native to the Mediterranean region of southern Europe and to northern Africa; it is also grown eastward through Syria and Palestine to the Himalaya Mountains. The cultivation of this crop is very ancient as seeds have been found among the remains of lake dwellings in Switzerland. The field pea was brought into the United States at an early date, as there are records of its having been grown in Virginia as early as 1636.

Since the field pea is extensively grown in Canada, it is frequently called the "Canadian" field pea. It is a staple crop in the New England states, in New York, Michigan, Wisconsin, Minnesota and in the eastern Dakotas. It is increasing in importance in Washington, Oregon, Idaho and western Montana.

Description.—The field pea is an annual with slender, hollow stems, 1½ to 10 feet long which stand erect only when there are plants from which they can secure support. The plants often have one or two stalks but seldom more than three, and the entire herbage is pale green with a whitish bloom on the surface. Each leaf has one to three pairs of leaflets, and is terminated by one or more pairs of slender, branched tendrils by which the plant fastens itself to supports. The flowers are reddish-purple, parti-colored or white, and usually two or three are borne by each flower stalk. The hanging pods, which are green, or less often yellow, are about 3 inches long and contain five to nine nearly round seeds.

The garden pea and the field pea resemble each other very closely since they belong to the same species. As a rule, the varieties with rounded yellowish or greenish seeds and white flowers are classed as field peas. In some cases the field pea varieties have yellow seeds and white flowers; in other cases the flowers are colored and the seeds are brown to black, marbled, mottled or speckled. There are all possible intergrades and frequently the same variety is used for garden and field purposes.

Adaptation.—The field pea requires a cool growing season, high temperatures being more injurious than frosts. The climatic requirements of the field pea limit its successful production as a summer crop to the northern states and Canada and to the mountainous sections of the western states. In the South it is grown as a winter crop. Rainfall is less important than temperature. In western Canada, 15 inches of rainfall will allow the production of a good crop, while a rainfall of 20 inches is not sufficient in Kansas, Nebraska and Colorado.

A well-drained soil is necessary for the successful production of the field pea and it thrives best on a rich, calcareous soil. If the soil is very

rich, the production of vines is great while the production of seed is small; on a poor soil the yield of both vines and seed are low.

Culture.—The Golden Vine is the best general purpose variety of the field pea; it is also the most widely grown variety. Among other varieties are the French June, Marrowfat, Prussian Blue and Wisconsin Blue.

When the field pea is to be grown as a summer crop, seeding should be done so that the pods will be set before warm weather arrives. In southern Canada and in the northern tier of states in the United States, seeding usually takes place from April to May 1; in the Intermountain region, crops are usually seeded from April 1 to 15; while in the southern and Pacific Coast states, where the crop is grown during the winter, the crop is seeded in the fall or early winter.

Under irrigation and in humid regions the rate of seeding varies from 1½ to 2 bushels for the small seeded varieties like the Golden Vine, to 3 to 3½ bushels for the large seeded varieties like the Marrowfat. Under dry conditions the rate of seeding is reduced about ½ bushel for each group. When a mixture of oats and field peas is used and seeded under conditions of abundant moisture, the field peas are sown at the rate of 1 bushel per acre and the oats at the rate of 1½ to 2 bushels. Under dry conditions this rate of seeding should be reversed. Field peas and oats require about the same conditions; the latter, however, will withstand more cold, and a mixture of field peas and oats is one of the oldest mixtures of a legume and a non-legume.

The crop is generally drilled or sown broadcast but the former method is to be recommended. In seeding the crop, one should see that inoculation is supplied since field peas, like other legumes, thrive best only when inoculated.

Harvesting.—The period of growth is approximately 60 to 100 days for hay, and 80 to 120 days for seed production. The crop should be cut for hay when most of the pods are well formed, and for seed when the pods are mature and the seeds are firm. When the peas are seeded with grain, the time of cutting may be determined by the ripeness of the grain; but as far as practicable, varieties of each that mature at the same time should be used.

Uses.—The seeds of the field pea are used both as human food and as feed for domestic animals. The plants also make an excellent hay especially when grown with a grain crop such as oats. The crop is grown more extensively for seed than for hay. In addition to these uses, field peas are valuable as pasturage and as a green manure and cover crop.

SUNFLOWERS

Origin and History.—The sunflower (*Helianthus annuus*) is a native of the Great Plains region from Nebraska to northern Mexico, where the wild forms frequently occupy large areas. Its natural range extends

to Peru and sometimes it is stated that the sunflower is also a native of Peru; this statement, however, is probably an error. The sunflower was one of the food plants of the American Indian, and was cultivated in Spain as early as 1597. The sunflowers cultivated in Europe were no doubt derived from plants developed by the American Indian.

The sunflower is now grown throughout North America. It is also found in South America, especially along the western coast from Columbia to Chile. The crop is grown to a limited extent in Australia, New Zealand, South Africa, Egypt, the Mediterranean region of Europe, India and China. The sunflower has reached its greatest usefulness in Russia and Hungary, especially in the former country.

Description.—The sunflower is an annual with a stout, erect, usually simple stem 1 to 3 inches in diameter and 5 to 20 feet in height; the stem becomes woody. The sunflower has alternate ovate leaves and one to six or more half-nodding heads with a brown or nearly black disk; it also has many golden-yellow rays, frequently 40 to 80. The sunflower which is used to the greatest extent agriculturally has a single large head which is commonly 6 to 12 inches in diameter.

Adaptation.—Sunflowers can be successfully grown in almost any part of the United States. However, the crop is not widely grown where other crops which will serve the same purposes do well. In the central and southern Great Plains the sorghums are superior silage plants, and in the corn belt corn surpasses the sunflower. In the southeastern states sunflowers cannot compete with corn, sorghum, Japanese cane and millet.

Sunflowers do comparatively well where the altitudes are high and where the temperature is relatively low during the growing season. Thus in the high altitudes of the western states, sunflowers are important since corn, sorghum and other crops do not produce as large a yield of silage. Sunflowers are much more resistant to frost than corn, and for this reason the sunflower crop may become of great importance in the New England states, northern New York, Michigan, Wisconsin, Minnesota, North Dakota, Montana, Washington, Oregon and some of the high valleys of the Rocky Mountain region.

The highest yields of sunflowers are secured when the crop is grown on rich soils but fair results have been secured on the poorer soils. However, no definite information can be given in the matter of yield other than to say that sunflowers will thrive wherever corn does well.

Uses.—In Russia the seeds of the sunflower are used extensively for food. In the United States the seeds are used chiefly for poultry feed and the entire plants, especially in recent years, are widely used for making silage.

Culture.—The chief variety of sunflower grown in this country is the Mammoth Russian. The time of seeding will of course vary but the

tests conducted in the various parts of the United States indicate that sunflowers should be seeded about the time corn is usually planted.

The crop may be planted with the ordinary corn planter in much the same way that corn is planted; or one may use the ordinary grain drill by stopping a certain number of holes or feeds in the drill box to give the proper distance between rows. The rows are usually 28 to 36 inches apart and the plants spaced about a foot apart in the row. For seeding in this manner a rate of 6 to 8 pounds of seed per acre is necessary. The crop is cultivated and harvested in the same way as corn.

Yields.—Vinall (1922) reports yields of 31 to 37.6 tons of sunflower silage per acre at Huntley, Montana; at Bozeman, Montana, the yield varied from 33.6 to 44.1 tons per acre. However, the yields will vary with conditions. For example, at the Washington Experiment Station the 2-year average yield of sunflower silage was 11.59 tons (Schafer and Westley, 1921).

The yield of sunflower seed varies greatly and yields ranging from 13 to 75 bushels to the acre are often reported.

MANGEL-WURZEL

Origin and History.—Mangel-wurzel, sometimes called "cow beets," "field beets" or "mangels," is considered a direct descendant of the chard which was utilized by the Greeks as early as 300 B.C. Beets were introduced by the early colonists and in 1806 the red beet was the only one listed for sale in America. At the present time, however, there are about twenty varieties.

The mangel is native to the Mediterranean and other parts of Europe. It was first cultivated for its leaves under the name of "chard," and in the sixteenth century it was grown in Germany and Italy for its roots which were used as feed for domestic animals. The crop is not widely grown in the United States but is more important in Canada.

Description.—The mangel is closely related to the chard, the table beet and the sugar beet, as they are all types of the beet (*Beta vulgaris*). The mangel is commonly a biennial but sometimes may be an annual or a triennial. It is generally called a root. It is in reality not a root but rather a modified stem and primary root, both of which are much thickened and closely united.

In shape mangels are designated as long, half-long, tankard, oval, or globe. The long and tankard types are the most popular, being easy to harvest and handle as they stand about one-half out of the ground. The skin of the mangels may be white, pink, red, orange, golden, purple or black; and the "roots" grow from one-half to three-fourths out of the ground. The mangel is usually not round in cross-section but has on two sides a shallow depression which is called the dimple, and the

fine fibrous roots should be limited to the depression. Good varieties of mangels contain about 12 per cent dry matter, about 50 per cent of this being sugar.

Adaptation.—The mangel is adapted to cool climates but an abundance of sunshine is desirable through the growing season. In the United States the crop is grown in the North Atlantic states and also to some extent in New York, Michigan, Wisconsin, Minnesota and a few other states.

Mangels require a deep, well-drained, moist, rich soil which is not too compact. Clay soils are not desirable and rich loams or sandy loams are most suitable. After the plants have secured a good start, they will withstand drought better than almost any other root crop.

Uses.—The mangel crop is used almost entirely as feed for domestic animals, largely for cattle and sheep. The tops, which are removed at harvest, are used for feed as well as the "roots."

Culture.—The seedbed for seeding mangels should be well prepared and free from weeds. Since the seeds of mangels are slow to germinate, since the seedlings grow slowly, and since weeds, if present, will likely crowd out the mangels, more care should be used in preparing the ground for mangels than for planting the ordinary crops.

Mangels may be seeded fairly early in the spring with an ordinary grain drill, a special sugar beet drill, or the ordinary garden drill. The seeds of mangels are produced in balls or bolts which contain from one to five seeds, and for this reason it is not possible to get the proper distribution when seeding. The right distribution is secured by "bunching," followed by thinning. The bunching consists in chopping out of the rows most of the plants not needed for a full stand. This chopping should be done before the sixth leaf appears. The bunches are left about 10 to 12 inches apart in the row; and immediately after the plants are bunched, each bunch is thinned by hand down to the best plant.

In seeding a rate of about 10 to 12 pounds of seed to the acre should be used and seeded in rows about 30 inches apart, the seeds being covered about 1 inch deep. The crop is cultivated, just after the thinning process, with some type of horse cultivator and the cultivations are continued until the leaves touch each other across the rows.

Mangels should be harvested as soon as they cease growing, this stage being indicated by the dropping of the outer leaves. Harvesting should take place before cold weather begins as the crop is injured by severe frosts. The "roots" may be pulled with a beet puller or by hand and the tops are wrung or cut off before storing. Soon after harvesting mangels should be stored in some place in which they will not freeze. A fair yield of mangels is 20 tons per acre, but a yield of 30 tons per acre is not uncommon.

SUGAR BEET

The sugar beet (*Beta vulgaris*) is an important root crop of the world, as approximately one-half of the world's sugar comes from this source.

Historical.—While beets have been cultivated for table use and for stock feed for many centuries, their value for sugar production was not recognized until about the middle of the eighteenth century. At that time German chemists found that the beet contained the highest percentage of sugar of many plants analyzed and began investigations in search of methods of extracting the sugar from them. The first beets analyzed contained only about 6 per cent of sugar, but by the selection of plants for high sugar content, many crops now yield 15 to 20 per cent.

Beet sugar did not appear on the market until 1812 and then in in small quantities. The commercial production of sugar beets in the United States, however, dates from 1869 when the first sugar factory was established in California.

Description.—The sugar beet and mangel are closely related and the plants show a close resemblance.

The sugar beet is a true biennial and does not produce seed until the second year. During the first year the beet root develops to full size and the second year produces a seed stalk which bears large quantities of seed. The seeds are borne in rough-coated capsules called "seed balls," which contain from three to seven seeds each.

Adaptation.—Successful sugar beet growing has been confined to the temperate region in practically all sugar beet producing countries. In warmer areas the roots are not usually sufficiently rich in sugar to make them profitable in sugar making. In colder areas the seasons are too short for the proper development of the crop.

Practically the entire northern half of the United States is climatically suited for the production of sugar beets, but labor and soil factors confine the crop to rather limited areas. The chief beet sugar producing states are Utah, Colorado, Michigan, Idaho, California, Wisconsin and Ohio. Since sugar beets may be grown successfully on practically all of the corn and potato soils of the northern part of the United States, their production will doubtless expand when economic conditions justify increased acreage (Fig. 88).

Propagation.—The propagation of sugar beets is from seeds. Roots intended for seed stocks are stored in cellars during the winter months. In the spring a sample is taken from each root for analysis, and only those showing a desirable percentage of sugar are planted. The seed for seeding is produced from those roots with high sugar content. Thus a constant selection for high sugar content is kept up. Sugar mill operators import the greater part of the seed used in the United States; the seed is then distributed to growers who grow the beets under contract.

Culture

Preparing the Seedbed.—Since the beet grows largely underground, a deep seedbed is necessary. This fact necessitates plowing and sometimes subsoiling. When practicable, the land should be plowed in the fall so that it may be worked early in the spring. Much care should be taken in the preparation of the seedbed and it should be thoroughly prepared and made free from weeds before the seeds are sown. Since the best plants are very small and weak when they first come up, poor stands usually result from seeding on rough, poorly prepared soils. If seeds are seeded in weedy seedbeds, much hand weeding must be resorted to, and it is much cheaper to prepare the seedbed thoroughly before seeding.

Planting.—With machines made for the purpose, the seeds are drilled in rows 14 to 30 inches apart. Experiments indicate that rows spaced 20 inches apart usually give best yields. A rate of 18 to 20 pounds of seed is required for seeding an acre. Though beets will withstand light frosts, it is usually best to delay seeding until the last killing frost date is passed.

Thinning.—Each seed ball will produce on the average about two plants, though a seed ball producing four or five plants is not uncommon. For this reason it is obviously impossible to distribute the seed so that an even stand will result. Since it is impossible to seed at the desired rate, the plants must be thinned. Thinning is done by first "blocking" with a hoe; in this process, plants are cut out with a hoe so that small bunches 8 or 10 inches apart remain. After blocking, each bunch is thinned to one plant. This is the most tedious and most particular work connected with beet growing as improper thinning results in lowered yields.

Cultivation.—A weeder or light harrow may be used for the first one or two cultivations, but afterwards frequent shallow cultivations with narrow-toothed cultivators should be given until the tops completely cover the ground. Usually two hand hoeings are necessary in the early growing season in order to keep the crop free from weeds.

Harvesting.—The harvesting may be divided into three operations, lifting, pulling and tipping. Lifting consists in plowing near the beets to loosen the soil so that they may be easily pulled. The pulling is done by hand, and the beets are thrown into piles of convenient size for loading.

Since the part of the beet that grows above the ground is not desired at the sugar factory as it is low in sugar and high in undesirable minerals, the top is removed by cutting off at the point of the lowest leaf scar. After the top is removed, the beets are hauled to the factory.

Yields.—The average yield of sugar beets for the United States is about 10 tons to the acre. However, a yield of less than 15 tons is not considered a satisfactory yield, and yields of 20 tons or more are not

uncommon. From 1,200 to 1,500 pounds of seed may be secured from an acre.

SUGAR CANE

Sugar cane (*Saccharum officinarum*) is a member of the grass family and is chiefly valued for the juices expressed from its stems. The juice from sugar cane differs from that of sorghum in that the sugar cane juice, when at the proper stage of maturity, contains sucrose or crystallizable sugar.

Historical.—Sugar cane is a native of New Guinea. It is supposed to have been carried to Africa from the East Indies and to have been introduced into southern Europe by the Portuguese, whence it was brought to the West Indies. From the West Indies sugar cane was introduced into Louisiana and Florida about the middle of the eighteenth century. Though the plant was known long before the Christian Era, it does not seem to have been of much importance until after the discovery of America.

Distribution in the United States.—The production of sugar from sugar cane in the continental United States is limited to Louisiana and Texas except for small quantities made by plantation mills. However, the crop is grown rather extensively for syrup manufacture in Mississippi, Alabama, Georgia, Florida and South Carolina as well as in Louisiana and Texas (Fig. 88).

Where sugar cane is produced for sugar making, it is usually grown on a very extensive scale, whole plantations often being devoted to the crop. On the other hand, the sugar cane for syrup is produced chiefly in small fields or patches, mainly for home use, with a small surplus for sale.

Description of the Plant.—A plant of sugar cane usually consists of a number of stalks growing together in a cluster. This cluster results from the fact that the main stem throws up additional stems from the underground nodes. The plant varies in height but under favorable conditions may reach a height of 15 feet or more. In tropical countries one planting may afford several harvests, the stubble remaining alive from season to season. This fact is true in the Gulf Coast region of the United States but in the northern part of the sugar cane belt the plants do not endure the winter and annual plantings are necessary.

The leaves of sugar cane are somewhat similar to those of corn. The leaf sheath folds around the stem and serves as a protection for the bud or eye which is borne at the node. The stem is jointed, but the internodes are much shorter than those of corn. Most of the sugar cane grown in the United States is harvested before the inflorescence appears. In tropical countries, as maturity approaches, the plant throws out a dense silky panicle or "arrow" at the top. The small inconspicuous

flowers are borne in spikelets which are surrounded by silky hairs. The percentage of fertile seeds produced in a panicle is very small, and these seeds lose their viability very soon after maturity.

Varieties.—The most popular types of sugar cane for syrup production are the purple or red and the striped or ribbon cane. These varieties are also used for sugar manufacture but two strains, D 74 and D 95, introduced by the Louisiana Experiment Station from Demerara, South America, are rapidly growing in popularity.

On account of its resistance to cold, Japanese sugar cane is important in the northern part of the sugar cane belt, but for syrup-making it is not considered as desirable as the other types where they can be grown. This variety is also grown in some sections as a forage plant.

Propagation.—Sugar cane is propagated by planting the stripped stalks. At each node these stalks have buds or eyes from which the new plants grow. The "seed stalks" may be planted in the fall where they are to grow; or they may be bedded so as to prevent freezing and planted in the spring. In breeding work, sugar cane is propagated from seeds but this task is slow and laborious.

Culture

Preparation of the Seedbed.—The preparation of the seedbed for sugar cane is much the same as that for corn except that it is usually more thorough. When the land is inclined to be wet, it is thrown into beds 5 to 7 feet broad, a water furrow being left between the beds.

Planting.—The crop may be planted either in the fall or in the spring. In the northern part of the sugar cane belt, spring planting is most common and in the southern section the bulk of the crop is planted in the fall. The spacing of the rows varies from 4 to 7 feet according to locality and the productivity of the soil. As the plants tiller more where conditions are most favorable for growth, the wider spaces are used when such conditions exist. The rows are opened with a plow and the stalks are distributed end to end in the row. A light furrow is then turned from both sides so as to cover the rows and leave the canes covered by 3 to 4 inches of soil.

Cultivation.—The first cultivation of sugar cane may be made with a smoothing harrow run across the ridges thrown up in covering the "seed stalks." Subsequent cultivations are much the same as those given to corn and should be given often enough to keep the weeds out of the crop until it completely shades the land.

Harvesting.—The crop is usually allowed to grow as late as possible in the fall and is not harvested until just before the killing frost date of the section. The harvesting consists of three operations: stripping the leaves, cutting off the top, and cutting the stalk. The leaves are usually

stripped by a hand implement specially devised for the purpose. The tops are cut with a heavy knife and then the stalks are cut off at the ground with a heavy knife or stout hoe. After the stalks are harvested, they are loaded on wagons or carts and hauled to the cane mill, where the juice is extracted and made into sugar or syrup.

Yields.—The average yield acre of sugar cane in the United States varies from 12 to 15 tons for the sandy uplands to 15 to 30 tons for the more productive alluvial soils. A good average yield of sugar is about 3,000 pounds to the acre. This is accompanied by a yield of molasses of 100 gallons or more. The yield of syrup varies from 250 to 600 gallons to the acre according to the number of tons produced and the kind of mill used in extracting the juice. The total sugar content of cane varies from 12 to 16 per cent.

FLAX

While flax (*Linum usitatissimum*) was formerly grown chiefly for its fiber, from which linen was made; at the present time the crop is produced in the United States almost exclusively for its seed, from which linseed oil is made.

Historical.—Flax has been grown from the earliest times of which we have records. It probably originated in the region around the Black Sea in Asiatic Turkey as it still grows wild in that locality. The cultivation of flax was carried from western Asia and Egypt into Europe and from there was introduced into America at an early date. In reference to its history in the United States, Ball and others (1923) state:

> Seed flax has held the unique position of a "pioneer crop" in the agriculture of the United States, as it has been grown largely as the first crop on newly turned virgin sod. The area of flax production, therefore, has moved westward with the settlement of new lands until now it has reached about the western limit of its migration.
>
> The census of 1850 showed Ohio and Kentucky to be the chief flaxseed-producing states in 1849. By 1859 flax was well established in Indiana and in 1869 in Illinois and Wisconsin. Ten years later, in 1879, Iowa was producing a considerable quantity of flaxseed, and by 1889 Minnesota, Iowa and South Dakota were the principal producing states. By 1899 North Dakota had taken the lead in the production of flaxseed; and with Minnesota and South Dakota, it still continues to produce the bulk of our crop.

The production of flax in the United States has rapidly decreased since 1902. This falling off is probably due to the increasing prevalence of flax wilt.

Description.—Common flax is an annual with a single upright stem and a long tap root with few small branches. The number and length of the branches depend largely upon the thickness of planting. Plants with plenty of room produce numerous branches, while those that are crowded branch sparingly. The plant grows 1 to 2 feet high according to soil

and climatic conditions. The leaves, which are alternate and lanceolate, are from ½ to 1½ inches long. The flowers are produced in a leafy, terminal panicle. They are light blue in color and about ½ inch across. The seeds are borne in a rounded capsule which contains from 8 to 10 seeds.

Adaptation.—Flax grows well on almost all types of soil but rather heavy loams seem to produce the best yields. As far as climate is concerned, the chief flax-producing areas are in the northern part of the temperate zone. In the United states, flax seems to give best results in the spring wheat section (Fig. 103). It was formerly thought that flax required very rich soils and was "hard on the land." It was, therefore, seeded chiefly on virgin soils. More recently it has been found that failures on old land are due to the prevalence of the flax wilt disease and not to a serious reduction of the productivity of the soil.

Uses.—Practically all of the flaxseed produced in the United States is utilized in the manufacture of linseed oil. The oil is used largely for paints and varnishes, for which purposes it is highly prized on account of its quick-drying properties. It is also used in printers' ink and in the manufacture of rubber substitutes.

The part of the seed remaining after the oil is removed is linseed meal, which contains 20 to 25 per cent of protein and is highly valued as a stock feed.

Flax straw is used for making linen and many coarser materials such as tow, binder twine, toweling and bagging.

Culture

Preparation of the Seedbed.—The usual practice in preparing land for seeding flax is to plow sod land in the fall or early spring and work it down with a harrow, just before seeding, until a well-prepared seedbed is made. A good seedbed, compact below and having a few inches of loose soil on top, seems to give the best condition for seeding. Old sods and pastured fields usually produce better yields of flax than land which is in a rotation of cultivated crops.

Seeding.—Flax may be seeded in the spring as soon as danger of frost is over. A rate of 2 to 3 pecks to the acre is used when grown for seed; a rate of 6 to 8 pecks is used when grown for fiber. The seed should be well cleaned before seeding and it is usually advisable to treat flax seed with a formaldehyde solution of the same strength as that recommended for the treatment of smut in oats. The seed is sown with an ordinary wheat drill to the depth of 1 to 2 inches and care should be taken to cover it to a uniform depth, since the crop will then mature more uniformly.

Harvesting.—The usual method of harvesting flax is with the grain binder. The crop cures readily in the shock and is not easily injured by

weather. The seed is removed from the straw with the ordinary grain threshing machine.

When the crop is harvested for fiber, it is pulled by hand and tied into shocks to cure. When properly cured, the grain is threshed and the straw is then put through the various processes necessary to remove the fiber.

RICE

Origin and History.—Rice (*Oryza sativa*), which is one of the oldest cultivated plants, was grown in China at least 4,000 years ago. It grows in the southern part of China and is evidently native to that country. It was introduced into India from China and was then introduced into western Asia, Egypt and southern Europe. It was introduced into South Carolina in 1694 and was grown in the Governor's garden in Charleston in that year.

In 1839 about 90 per cent of the rice of the United States was grown on the tidal lands of South Carolina, North Carolina and Georgia. In that year South Carolina produced 70 per cent of the crop and Louisiana less than 4 per cent. By 1849 the production had greatly increased, especially in Mississippi, Alabama and Florida, but South Carolina, North Carolina and Georgia still led in production. In 1859 South Carolina produced more than 60 per cent of the rice crop and South Carolina, North Carolina and Georgia together produced 90 per cent of the production.

The Civil War had a profound effect on rice cultivation in the South Atlantic states in that property was destroyed, money and labor became scarce and the plantations could not be extensively cultivated on account of the lack of funds to finance the production under changed labor conditions. As a result, rice culture became less profitable. However, rice production increased along the Mississippi River in Louisiana after the Civil War partly because less labor was required for its production than for the production of sugar cane. Rice became important in Louisiana about 1887 when it was definitely determined that it could be profitably grown in the prairies of southwestern Louisiana. Since the prairies are divided and broken here and there by sluggish streams, it is easy to secure irrigation water. In 1887 Louisiana became the largest rice-producing state and still leads. As a result of the culture of rice in Louisiana, the production of the crop was developed in southeastern Texas and eastern Arkansas.

In 1912 the first commercial crop of rice was produced in California, mostly in the vicinity of Biggs, in Butte County. In 1922 California ranked fourth in acreage and second in production of rice.

Production.—Rice is grown in all tropical countries but the bulk of the crop is grown in the eastern and southeastern parts of Asia, including the neighboring islands, especially in Japan and China. The seven countries, India, Japan, China, Java, Indo-China, Siam and Korea pro-

duced about 70 per cent of the rice crop in 1920. Exclusive of Asia, the main warm-temperate areas of production are in the United States, Spain, Italy and Egypt; and of these the United States leads with about 1 per cent of the world production.

In the United States the 5-year average annual production for the country as a whole during the period, 1910 to 1914, was 24,378,000 bushels with an average yield per acre of 33.3 bushels. During the 5-year period, 1915 to 1919, the average annual production was 37,028,000 bushels with an average yield of 38.5 bushels per acre. Of the 37,612,000 bushels of rice produced in the United States in 1921, Louisiana is to be credited with 17,280,000 bushels, California with 7,290,000 bushels, Arkansas with 6,688,000 bushels, Texas with 5,993,000 bushels and South Carolina with 175,000 bushels (Fig. 103).

Description.—Rice does not differ greatly in growth from the other cereals. It is closely related to the wild rices (*Zizania*), which grow wild in the regions of eastern America and eastern Asia. Rice is an annual. The root system is fibrous and shallow, the culms average 4 to 5 feet in height, and like other cereals rice tillers abundantly under favorable conditions. The flowers are produced in panicles which are somewhat more compact than those of oats, and the one-flowered spikelets are borne on short pedicels. The outer glumes are short scales; the flowering glume, which is sometimes awned, and the palea make up the hull or husk which envelopes the kernel and remains attached to the grain in threshing. The hull varies in color from light to dark brown. Rice which is enclosed in the hull is called "paddy," and that from which the hull has been removed is known as "cleaned" rice. The kernels of the latter are slightly furrowed, hard and white in color.

Adaptation.—Some of the factors affecting the production of lowland rice are irrigation water, precipitation, temperature and soil; and the most important one is irrigation water. The production of rice is dependent upon an abundant supply of fresh water, as a depth of practically 6 inches of water must be maintained for a period of not less than 75 days. The rice area is also limited by rainfall and temperature, as the crop requires a relatively high humidity and an average temperature of 70° F. during the 4 to 6 months of growing season. The precipitation should be well distributed and should be between 50 and 60 inches within the area of production and upon the watersheds of the streams furnishing water for irrigation.

A heavy soil is more desirable than a lighter type and a subsoil impervious to water must be underneath. The land used for lowland rice production must be in level tracts.

Uses.—Rice is used mainly for human consumption and is one of the most important starchy foods of the world, especially in the Orient.

Culture

Types and Varieties.—There are two general types of rice, the *lowland* and the *upland*. The former is grown on rather low, level land which can be irrigated, and the latter is grown without irrigation just as corn and cotton are grown. Practically all the rice produced in the United States is of the lowland type.

Rice may also be classified as *long grain, short grain* and *medium grain,* depending on the length of the grains. The seeds of the long grain rice are long and narrow and average in length $2\frac{1}{2}$ seeds and in width 8 seeds to the inch. The short grain seeds average 4 seeds in length and 7 seeds in width to the inch; while the medium grain seeds average $3\frac{1}{2}$ seeds in length and $7\frac{1}{5}$ seeds in width to an inch. The leading variety of the long-grain type is Honduras, of the short-grain type Wataribune, and of the medium-grain type, Blue Rose.

Seeding.—In the preparation of the land for rice, the field is plowed either in the spring or in the fall and prepared much as for the other cereals. The seeds may be sown broadcast or drilled with a grain drill, the latter method being preferable. A rate of 1 to 2 bushels of seed is used per acre, and the crop is seeded from the middle of April to the last of May. Graded seeds, which have the hulls attached, should be used and the depth of planting should not exceed 2 inches, since poor seeds and too deep planting are likely to result in poor stands.

Application of Water.—The water should be first applied when the plants have reached a height of from 6 to 8 inches. At this time the subfields are submerged to a depth of 1 to 2 inches and the depth of water is slowly increased until the maximum depth of 5 inches is obtained when the plants should be at least 2 feet in height. Throughout the growing season the maximum depth of water is maintained by supplying fresh water to restore that lost by seepage, evaporation and transpiration. When the crop begins to ripen, the water is drawn off to allow the ground to dry out sufficiently for harvesting.

Harvesting.—Rice should be cut somewhat before maturity; the proper stage is indicated by the position of the heads, which are well turned down. At this time the kernels in the lower part of the heads have not entirely hardened.

The ordinary grain binder is usually used in harvesting the crop and the bundles are shocked and cured in the field like the other cereals.

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